Sandia National Laboratories

Results of the Technical Areas III and V RCRA Facility Investigation

June 1996

Environmental
Restoration
Project

United States Department of Energy
Albuquerque Operations Office

RESULTS OF THE TECHNICAL AREAS III AND V RCRA FACILITY INVESTIGATION

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Department 7582: Environmental Restoration for Technical Areas and Miscellaneous Sites

EXECUTIVE SUMMARY

A Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) was conducted in 1994 and 1995 at 21 Environmental Restoration (ER) sites within Technical Areas III and V (TA-III/V) at Sandia National Laboratories in Albuquerque, New Mexico (SNL/NM). This report details the investigations at each of the sites.

In the RFI Work Plan (SNL/NM 1993a, 1993b), the ER sites were grouped into five categories:

1. Sites proposed for No Further Action (NFA);
2. Potential petroleum-impacted sites;
3. Sites potentially impacted only by hazardous constituents of concern (COCs);
4. Sites potentially impacted only by radioactive constituents; and
5. Sites potentially impacted by both hazardous and radioactive compounds.

The sites were investigated separately and are discussed in the report in individual sections (Sections 3.0 through 23.0).

Three of the sites proposed for NFA (ER Sites 105, 188, and 195) were submitted to the U.S. Environmental Protection Agency (EPA) in 1995 for administrative NFA decisions. All three were granted NFA status in July 1995.

Based on confirmatory sampling, the following sites are proposed for NFA in this RFI report: Sites 26, 31, 34, 35, 36, 37, 51, 78, 100, 102, 107, 111, 196, and 241. A Class III permit modification request will be submitted following final determinations on sites addressed within this RFI report. This RFI report constitutes the NFA proposals for these sites. Most sites in this group exhibited no contamination above background levels; the remainder of these sites were contaminated at levels far below regulatory limits. Although Site 107 falls into this group, it has been identified as the preferred site for a future temporary unit and corrective action management unit (TU/CAMU) for the ER Project. Thus additional activities related to its TU/CAMU status will be conducted.

Several of the ER sites are still active (i.e., testing is currently being conducted at or immediately adjacent to the sites). Because of this, only limited investigations were conducted at Sites 26, 83, and 84 where ongoing testing significantly impacts thorough site characterization. Investigations at these sites included geophysical surveys to identify buried material at Sites 26 and 84 and surface radiation surveys (discussed below) at Sites 83 and 84. Investigations will be completed when these sites are decommissioned or placed in final inactive status. Site 240 was reactivated for testing after site characterization was completed. Thus, proposed geophysical investigations of Site 240 will be postponed until the site is placed in final inactive status.

A Voluntary Corrective Measure (VCM) was performed to survey and remove surface radiation hazards associated with testing conducted at several ER sites. Sites 18, 83, 84, 102, 240, and 241 were surveyed for radioactive anomalies. Removal activities were conducted at sites where anomalies were demonstrated to exist (Sites 18, 83, 84, and 240).

A VCM also was conducted at the Gas Cylinder Disposal Pit (Site 78) to mitigate the immediate hazard posed to human health and the environment. The site exhibited many unruptured gas cylinders containing hazardous and toxic gases, high-explosive (HE) residues, and radioactively contaminated soil and slag. The VCM was accelerated from the original schedule of site assessment, remedy selection, and full-scale remediation. The entire contents of the pit were removed and examined, the contaminants were identified, and hazardous, radioactive, and solid wastes were disposed in a manner appropriate to regulatory requirements. As indicated above, Site 78 is proposed for NFA based on the results of the VCM.

The investigation of Site 18 revealed limited chemical contamination for which a VCM is planned. Site 18 exhibited elevated levels of polychlorinated biphenyls (PCBs) in an area approximately 10 feet by 80 feet. The contamination is believed to be restricted to the upper few inches of soil; shallow excavation (scraping the soil) is proposed to remediate the hazard posed by the PCBs. The results of the VCM at Site 18 will be documented in an NFA proposal, and the adequacy of the cleanup will be evaluated in a Class 3 permit modification process.

ACRONYMS AND ABBREVIATIONS

AIP	Agreement in Principle
AMSL	above mean sea level
ASTM	American Society for Testing and Materials
CA	Corrective Action
CEARP	Comprehensive Environmental Assessment and Response Program
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
CMS	corrective measures study
Cn	critical number
COC	constituent of concern
CWL	Chemical Waste Landfill
DCP	direct current plasma
DNT	dinitrotoluene
DOE	U.S. Department of Energy
DOE/AL	U.S. Department of Energy/Albuquerque Operations Office
DOT	U.S. Department of Transportation
DQO	Data Quality Objective
DU	depleted uranium
EA	Environmental Assessment
EDE	effective dose equivalent
EM	electromagnetic
EORC	Environmental Operations Records Center
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
ES&H	Environment, Safety, and Health
FID	flame ionization detector
FOP	Field Operating Procedure
GC	gas chromatograph
GC/MS	gas chromatograph/mass spectrometer
GCDP	Gas Cylinder Disposal Pit
GIF	Gamma Irradiation Facility
GIS	Geographic Information System
GJPO	Grand Junction Projects Office (DOE)
GM	Geiger-Müller
GPS	Global Positioning System
HASP	Health and Safety Plan
HE	high explosive
HERMES	High-Energy Radiation Megavolt Electron Source
HPCA	High Pressure Container Access
HPGE	high purity germanium

HSWA	Hazardous and Solid Waste Amendment
HWMF	Hazardous Waste Management Facility
ICM	interim corrective measure
ICP	inductively coupled plasma
ID	inner diameter
IH	industrial hygiene
KAFB	Kirtland Air Force Base
KAO	Kirtland Area Office
LCS	laboratory control sample
LIHE	light-initiated high explosive
LLW	low-level waste
LWDS	Liquid Waste Disposal System
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MDA	minimum detectable activity
MDL	method detection limit
ms/msd	matrix spike/matrix spike duplicate
MSA	Mine Safety Appliances
MSD	mass selective detector
MSDS	Material Safety Data Sheet
MWL	Mixed Waste Landfill
NA	not applicable
ND	nondetect
NFA	No Further Action
NIST	National Institute of Standards and Testing
NMED	New Mexico Environment Department
NMUSTR	New Mexico Underground Storage Tank Regulations
NRC	Nuclear Regulatory Commission
OD	outer diameter
OP	Operating Procedure
OSI	on-site investigation
OVA	organic vapor analyzer
PA	preliminary assessment
PCB	polychlorinated biphenyl
PCE	tetrachloroethene (tetrachloroethylene or perchloroethylene)
PIC	pressurized ionization chamber
PID	photoionization detector
PIP	Project Implementation Plan
PLQ	practical limit of quantitation
PPE	personal protective equipment
PVC	polyvinyl chloride

QA	quality assurance
QC	quality control
QAP	Quality Assurance Program
QAPjP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
RMMA	Radioactive Materials Management Area
SAP	Sampling and Analysis Plan
SASN	silver acetylyde-silver nitrate
SI	site investigation
SMO	Sample Management Office
SNL/NM	Sandia National Laboratories/New Mexico
SVOC	semivolatile organic compound
SWHC	Site-Wide Hydrogeologic Characterization
SWMU	Solid Waste Management Unit
TA	Technical Area
TAL	target analyte list
TCA	trichloroethane
TCE	trichloroethene (trichloroethylene)
TCLP	Toxicity Characteristic Leaching Procedure
TD/GC	thermal desorption/gas chromatography
TNT	trinitrotoluene
TPH	total petroleum hydrocarbon
TU-CAMU	temporary unit and corrective action management unit
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
UST	underground storage tank
UTL	upper tolerance limit
VCM	Voluntary Corrective Measure
VOC	volatile organic compound
WRS	Wilcoxon Rank Sum
XRF	X-ray fluorescence

ABBREVIATIONS

Ag	silver
Am-241	americium-241
As	arsenic
Ba	barium
Be	beryllium

Bldg	Building
bgs	below ground surface
°C	degrees Celsius
Cd	cadmium
cm	centimeter(s)
C_n	critical number
Co-60	cobalt-60
cpm	counts per minute
cps	counts per second
Cr	chromium
Cs-137	cesium-137
Cu	copper
°F	degrees Fahrenheit
ft	foot (or feet)
ft^2	square feet
ft^3	cubic feet
g	gram(s)
gal.	gallon(s)
hr	hour(s)
in.	inch(es)
kg	kilogram(s)
km	kilometer(s)
L	liter(s)
lb	pound(s)
MBK	2-hexanone
MEK	2-butanone
MIBK	methyl isobutyl ketone
m	meter(s)
m^2	square meter(s)
mg	milligram(s)
mg/L	milligrams per liter
mg/kg	milligrams per kilogram
µg	microgram
µg/kg	microgram(s) per kilogram
µR/hr	microroentgens per hour
mrem/yr	millirem per year
mi	mile(s)
min	minute(s)
mL	milliliter(s)
mm	millimeter(s)
mph	miles per hour

NaI	sodium iodide
Ni	nickel
Pb	lead
pCi/L	picocuries per liter
pCi/g	picocuries per gram
ppb	parts per billion
ppm	parts per million
psig	pounds per square inch, gauge
Se	selenium
sec	second(s)
Th	thorium
U	uranium
U_{tot}	total uranium
yd	yard(s)
yd^3	cubic yard(s)
yr	year
Zn	zinc

1.0 INTRODUCTION

1.1 Site Background

The Sandia National Laboratories/New Mexico (SNL/NM) Environmental Restoration (ER) Project is chartered with the assessment and cleanup of inactive waste sites at its facilities. This document presents the results of the Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) of the SNL/NM sites within Technical Areas III and V (TA-III/V). The sites were identified during a preliminary assessment/site investigation (PA/SI) (DOE 1987) as potential areas of concern or as solid waste management units (SWMUs) as a result of past practices in TA-III/V. Detailed descriptions of these sites are found in the TA-III/V RFI Work Plan (SNL/NM 1993a, 1993b). The purpose of the RFI was to determine the presence or absence of contamination at each of the TA-III/V ER sites.

Sandia Corporation, a subsidiary of Lockheed Martin Corporation, operates SNL/NM as a prime contractor to the U.S. Department of Energy (DOE), which owns SNL/NM. SNL/NM conducts research, development, design, and testing of nuclear and conventional weapons, energy systems, and other programs. Figure 1-1 identifies SNL/NM and its technical areas in relation to Kirtland Air Force Base (KAFB) and the city of Albuquerque, and several surrounding physical features. TA-III/V were established in 1953 for testing weapons components in a variety of natural and simulated environments. TA-III/V are located approximately 6 kilometers (km) south of the main laboratories and offices known as Technical Area I (TA-I) (Figure 1-1).

1.2 RFI Work Plan Overview and Objectives

This RFI has been conducted in accordance with the U.S. Environmental Protection Agency (EPA)-approved TA-III/V RFI Work Plan (SNL/NM 1993a) and its amendment (SNL/NM 1993b). A total of 19 sites in TA-III/V were originally identified as requiring investigation. Varying levels of investigation were conducted at all sites originally identified in the RFI Work Plan. Table 1-1 provides a summary of the sites, their status, and the field investigations conducted at each site and Figure 1-2 shows the location of each site.

Sites were classified as active and inactive, based on use at the time of this RFI. Both active and inactive sites were investigated but full investigation and remediation of active sites was postponed until facility decommissioning. Two sites that were originally grouped together in the Work Plan were subdivided based on physical separation and difference in historical activities: Site 18 was divided into Site 18 (Concrete Pad) and Site 241 (Storage Yard); Site 83 was divided into Site 83 (Long Sled Track) and Site 240 (Short Sled Track).

The objectives of the RFI were to identify the nature and extent of contamination at sites within TA-III/V, evaluate potential risks posed by the contamination, and provide guidance for selecting remedial alternatives. The objective of this RFI report is to document and transmit this information to all stakeholders, including SNL/NM, the DOE, the EPA, the New Mexico Environment Department (NMED), and the general public.

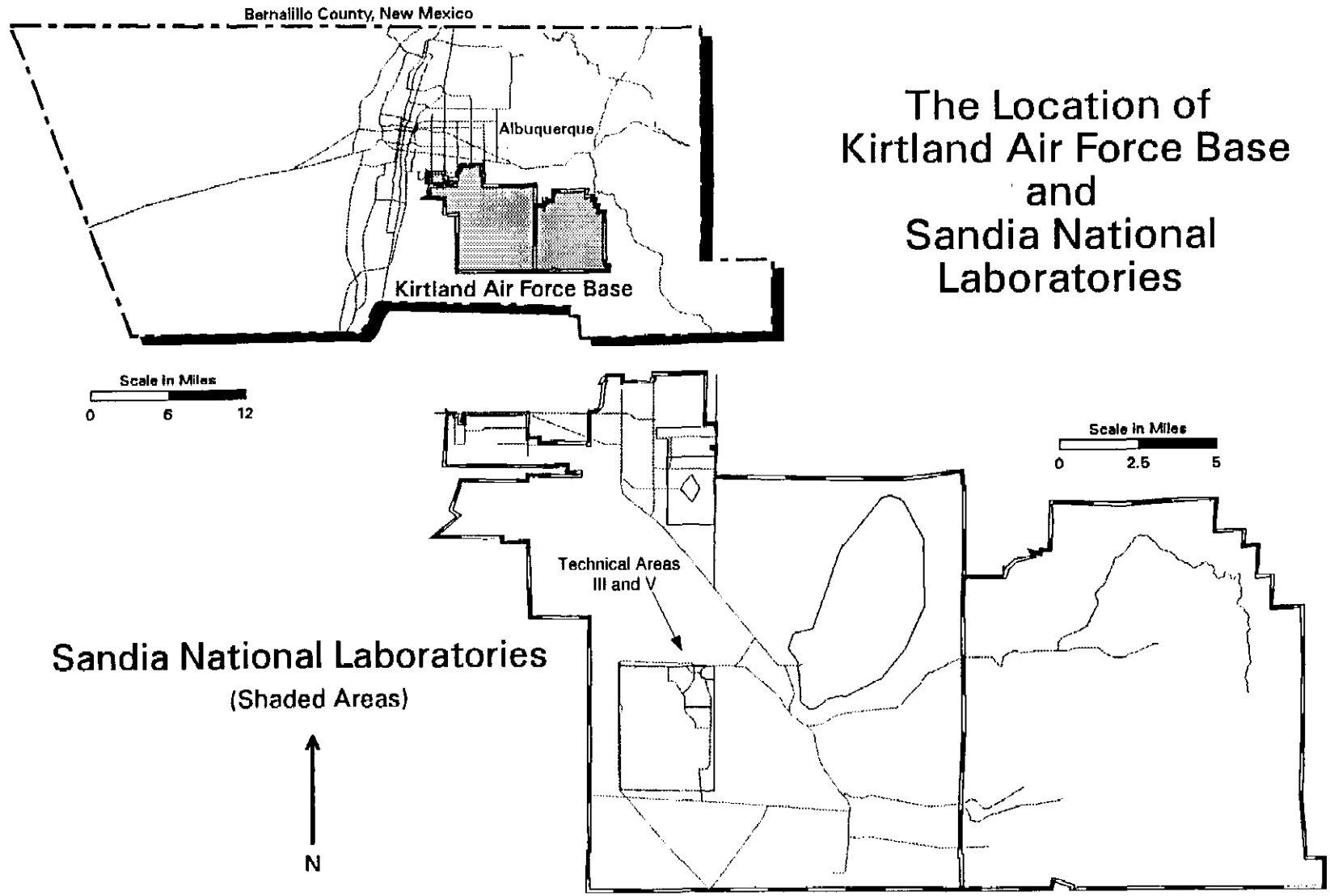


Figure 1-1 Location of Technical Areas III and V at Sandia National Laboratories, Albuquerque

Table 1-1
Summary of Environmental Restoration Sites Within Technical Areas III and V

Site Number	Site Name	Location	Areal Extent	Potential Contaminants[a]/ Detected During RFI?	Period of Operation (Status)	Sampling Method and Date	Total Samples	Field Screen Samples	Off-Site Analyses	Notes[b]
18	Concrete Pad	Central TA-III; South of Short Sled Track.	125 ft by 400 ft	Metals/Yes Radionuclides/Yes HEs/No Oil/Yes PCBs/Yes	1979 - present (Active).	Phase I: Surface, 04/27/94.	43	43	12	Rad. VCM completed. Extent of contamination defined for metals, PCBs, and TPH.
						Phase II: Auger, 01/24/95.	13	13	9	VCM planned.
26	Burial Site	West TA-III; West of Long Sled Track.	145 acres	Metals/NA[c] Radionuclides/Yes	Prior to 1989 (Inactive). Co-located with active Long Sled Track.	NA	NA	NA	NA	Geophysics done; found potential burials. These to be investigated with Site 83. Proposed for NFA.
31	Transformer Oil Spill	Central TA-III; Centrifuge Facility.	20 ft by 20 ft	Oil/No PCBs/No	1971 - present (Active).	Surface, 03/29/94.	11	3	11	No COCs above background. Proposed for NFA.
34	Centrifuge Oil Spill	Central TA-III; Centrifuge Facility.	90-ft diameter	Oil/No	1955 - present (Active).	Shallow subsurface, 05/20/95.	18	18	10	No COCs above background. Proposed for NFA.
35	Vibration Facility Oil Spill	Central TA-III.	20 ft by 50 ft	Oil/Yes PCBs/No	1955 - present (Active).	Phase I: Surface, 04/15/94.	4	0	4	Extent of oil defined. Proposed for NFA.
						Phase II: Shallow subsurface, 06/29/94.	13	13	4	

[a]Contaminants as follows: HEs = high explosives; PCBs = polychlorinated biphenyls; VOCs = volatile organic compounds.
[b]VCM = Voluntary Corrective Measure; TPH = Total petroleum hydrocarbons; NFA = No Further Action; COC = constituent of concern.
[c]NA = Not applicable. These sites were not sampled during the RCRA Facility Investigation (RFI); see Notes column.

Table 1-1
Summary of Environmental Restoration Sites Within Technical Areas III and V (Continued)

Site Number	Site Name	Location	Areal Extent	Potential Contaminants[a]/ Detected During RFI?	Period of Operation (Status)	Sampling Method and Date	Total Samples	Field Screen Samples	Off-Site Analyses	Notes[b]
36	HERMES Oil Spill	Central TA-V; North of Bldg 6596.	1 acre	Oil/Yes VOCs/Yes	1968 - 1989 (Inactive).	Phase I: Shallow subsurface, 07/6/94.	28	28	11	No oil detected in shallow subsurface. Defined extent of oil and VOCs.
						Phase II: Drilling, 03/10/95.	40	40	36	Proposed for NFA.
37	PROTO Oil Spill	Central TA-V; East of Bldg 6597.	1 acre	Oil/No	1978 - 1989 (Inactive).	Auger, 06/9/94.	23	23	8	No COCs above background. Proposed for NFA.
51	Bldg 6924 Pad, Tank, Pit	Southeast TA-III; Northwest of Site 241.	1/2 acre	Metals/Yes HEs/No VOCs/No	1963 - 1990 (Inactive).	Excavation, 09/6/94.	5	4	5	No COCs above background. Proposed for NFA.
78	Gas Cylinder Disposal Pit	Southeast TA-III; East of Chemical Waste Landfill.	80 ft by 180 ft	Toxic, corrosive, reactive, and flammable gases/Yes Radionuclides/Yes Metals/Yes HEs/Yes	1963 - 1984 (Inactive).	Phase I: Excavation - Radioactive.	94	386	91	Health and safety and geophysics surveys. Began VCM 07/94; finished 02/95.
						Phase I: Excavation - Chemical.	94	37	186	Detected chromium, thorium, gases, and reactive chemicals.
						Phase II: Gas analyses.	97	0	97	
						Phase II: Reactive chemicals.	32	32	0	No off-site analysis of reactive chemicals was feasible.
						Phase III: Confirmatory shallow subsurface.	20	0	20	No COCs above background during Phase III. Proposed for NFA.

[a]Contaminants as follows: HEs = high explosives; PCBs = polychlorinated biphenyls; VOCs = volatile organic compounds.
[b]VCM = Voluntary Corrective Measure; TPH = Total petroleum hydrocarbons; NFA = No Further Action; COC = constituent of concern.
[c]NA = Not applicable. These sites were not sampled during the RCRA Facility Investigation (RFI); see Notes column.

Table 1-1
Summary of Environmental Restoration Sites Within Technical Areas III and V (Continued)

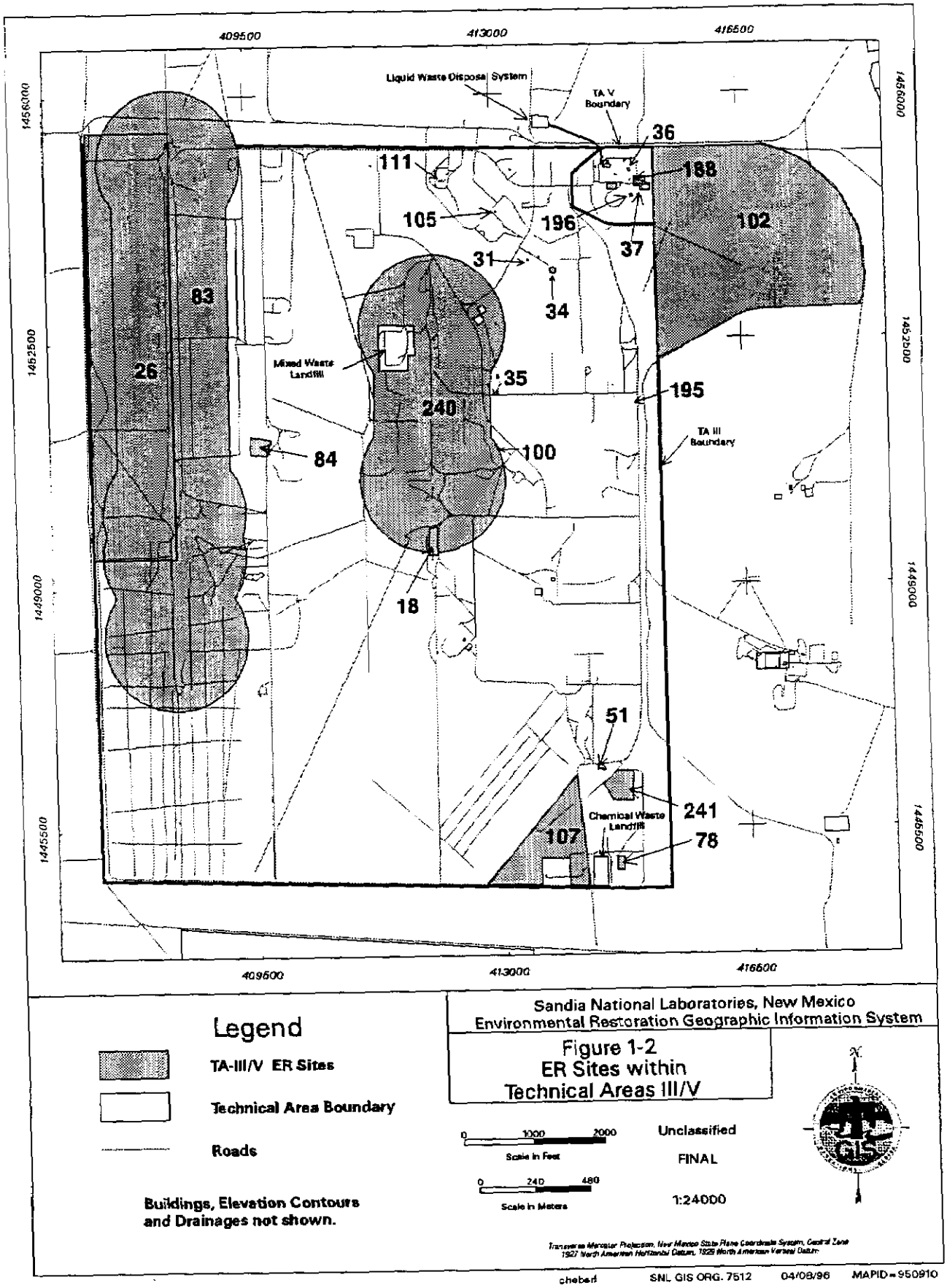
Site Number	Site Name	Location	Areal Extent	Potential Contaminants[a]/ Detected During RFI?	Period of Operation (Status)	Sampling Method and Date	Total Samples	Field Screen Samples	Off-Site Analyses	Notes[b]
83	Long Sled Track	West TA-III boundary.	350 acres	Metals/NA[c] HEs/NA Radionuclides/Yes	1966 - present (Active).	Surface, 04/15/94.	6	0	6	Minor surface sampling done. Rad. VCM completed. Full RFI when site deemed inactive.
84	Gun Facilities	West-central TA-III; East of Long Sled Track.	2 acres	Metals/NA HEs/NA Radionuclides/Yes	1965 - present (Active).	NA	NA	NA	NA	Rad. VCM completed. Full RFI when site deemed inactive.
100	Bldg 6620 Drain/Sump	Central TA-III, immediately southeast of Short Sled Track.	25 ft by 60 ft	Metals/NA HEs/NA	1958 - unknown (Inactive).	Exploratory trenching, 07/25/94.	0	0	0	Site not located during RFI. Proposed for NFA.
102	Radioactive Disposal Area	East of TA-V.	155 acres	Radionuclides/No	Unknown - 1967 (Inactive).	Excavation, 07/25/94.	3	0	3	Rad. survey done. No COCs above background. Proposed for NFA.
105	Mercury Spill at Bldg 6536	North-central TA-III.	20 ft by 20 ft	Mercury/NA	1972 - 1985 (Inactive).	Document search.	NA	NA	NA	Administrative NFA approved July 1995.
107	Explosives Test Area	Southeast TA-III; West of Chemical Waste Landfill.	25 acres	Metals/No HEs/No Nitrate and nitrite/No Radionuclides/No	1953 - 1972 (Inactive).	Surface, 05/17/94.	11	11	11	No COCs above background. Proposed for NFA. Future site of TU-CAMU.

[a]Contaminants as follows: HEs = high explosives; PCBs = polychlorinated biphenyls; VOCs = volatile organic compounds.
[b]VCM = Voluntary Corrective Measure; TPH = Total petroleum hydrocarbons; NFA = No Further Action; COC = constituent of concern.
[c]NA = Not applicable. These sites were not sampled during the RCRA Facility Investigation (RFI); see Notes column.

Table 1-1
Summary of Environmental Restoration Sites Within Technical Areas III and V (Concluded)

Site Number	Site Name	Location	Areal Extent	Potential Contaminants[a]/ Detected During RFI?	Period of Operation (Status)	Sampling Method and Date	Total Samples	Field Screen Samples	Off-Site Analyses	Notes[b]
111	Bldg 6715 Sump/Drain	North-central TA-III.	20 ft by 20 ft	Silver/No HEs/No VOCs/No	1971 - 1988 (Inactive).	Shallow subsurface, 06/17/94.	10	9	4	No COCs above background. Proposed for NFA.
188	Bldg 6597 Aboveground Spill Contain.	TA-V; co-located with Site 37.	15 ft by 25 ft	Used oil/NA[c]	1983 - 1986 (?) (Inactive).	Aerial photographs; confirmatory sampling.	37	22	22	Administrative NFA approved July 1995 - water tanks.
195	Experimental Test Pit	East-central TA-III.	6 ft by 6 ft	Cobalt-60/NA	1955 - 1956 (Inactive).	Document search.	NA	NA	NA	Administrative NFA approved July 1995.
196	TA-V Cistern	South TA-V; West of Bldg 6597.	25-ft diameter	Metals/Yes Oil/Yes VOCs/No	Unknown - 1989 (Inactive).	Phase I: Sludge sampling, 06/27/94 and 10/10/94.	4	3	1	Defined extent of metals in soil. No VOCs or PCBs. Proposed for NFA.
						Phase II: Excavation, 05/95.	2	0	2	
						Phase III: Auger, 06/5/95.	26	26	3	
240	Short Sled Track	Central TA-III.	160 acres	Metals/Yes HEs/No Radionuclides/Yes	1951 - 1966 (Inactive).	Surface, 06/13/94 and 06/22/94.	201	40	40	Rad. VCM completed. Detected rad. and lead.
241	Storage Yard	Southeast TA-III, North of Site 78.	3 acres	Metals/Yes HEs/No Radionuclides/No	1953 - 1994 (Inactive).	Surface, 05/24/94.	29	29	16	Defined extent of lead. Proposed for NFA.

[a]Contaminants as follows: HEs = high explosives; PCBs = polychlorinated biphenyls; VOCs = volatile organic compounds.
[b]VCM = Voluntary Corrective Measure; TPH = Total petroleum hydrocarbons; NFA = No Further Action; COC = constituent of concern.
[c]NA = Not applicable. These sites were not sampled during the RCRA Facility Investigation (RFI); see Notes column.


409500
413000
416500
1456000
1452500
1449000
1445500
Liquid Waste Disposal System
TA V Boundary
36
111
188
105
196
37
102
31
34
83
26
Mixed Waste Landfill
35
195
240
TA III Boundary
84
100
18
51
241
Chemical Waste Landfill
107
78
Legend
TA-III/V ER Sites
Technical Area Boundary
Roads
Buildings, Elevation Contours and Drainages not shown.
Sandia National Laboratories, New Mexico
Environmental Restoration Geographic Information System
Figure 1-2
ER Sites within
Technical Areas III/V
0 1000 2000
Scale in Feet
0 240 480
Scale in Meters
Unclassified
FINAL
1:24000
N
Transverse Mercator Projection, New Mexico State Plane Coordinate System, Central Zone
1927 North American Horizontal Datum, 1929 North American Vertical Datum
cheberl
SNL GIS ORG. 7512
04/08/96
MAPID = 950910

This RFI report consists of an executive summary, an introduction, a discussion of the Sampling and Analysis Program, descriptions of investigations conducted at individual sites, Voluntary Corrective Measures (VCMs) conducted at several sites, a summary and conclusion, a list of references, and supporting documentation in several appendices.

1.3 Facility Setting

SNL/NM consists of 2,820 acres of research laboratories and office facilities entirely contained within the 52,223-acre confines of KAFB (Figure 1-1). KAFB is bounded on the north and northwest by the city of Albuquerque, on the east by the Cibola National Forest, on the south by the Isleta Indian Reservation, and on the west by land owned by the State of New Mexico, the KAFB buffer zones, and the Albuquerque International Airport. Cibola National Forest access is controlled by the U.S. Forest Service (USFS) and is restricted within the buffer zones on the southwest corner of the base and within the Isleta Indian Reservation.

KAFB is located on a high, arid mesa (mean elevation of 5,350 feet [ft]) approximately 5 miles (mi) east of the Rio Grande. The mesa is cut by Tijeras Arroyo, which runs east-west and ultimately drains into the Rio Grande. The east side of KAFB is bounded by the southern end of the Sandia Mountains and the Manzanita Mountains. Most of the area is relatively flat, although the eastern portions of KAFB and SNL/NM extend into the Manzanita Mountains where some of the terrain is precipitous, rough, and cut by numerous arroyos (ERDA 1977).

1.4 Climate

The climate for SNL/NM is typical of high altitude, dry continental climates with a normal daily winter temperature range of 23 degrees Fahrenheit (°F) to 52°F and a normal daily summer temperature range of 57°F to 91°F (Bonzon et al. 1974). The average annual precipitation for the Albuquerque area is 8.54 inches (in.), and most rain occurs in the summer months (Williams 1986). Wind speeds seldom exceed 32 miles per hour (mph) but strong east winds, often accompanied by blowing dust, can occur (Bonzon et al. 1974).

1.5 Geology

The Albuquerque-Belen structural basin is one of the largest north- to south-trending basins in the Rio Grande Rift. The basin is a compound graben measuring 90 mi long and 30 mi wide, bordered by uplifted fault blocks to the east and west (Bjorklund and Maxwell 1961). The eastern boundary is marked by the Sandia, Manzanita, and Manzano mountains. The western side of the basin is bounded by the Lucero uplift, with the Ladron Mountains to the south and minor physiographic relief on the northwest side of the basin.

During the Miocene and Pliocene epochs, erosion from the surrounding highlands filled the Albuquerque Basin with up to 10,000 ft of sediments. This sequence of sediments is called the Santa Fe Group and consists of debris flows and channel, floodplain, and aeolian deposits; the Santa Fe Group thins toward the edges of the basin and is truncated by the bounding uplifts. The Santa Fe Group sediments are

interbedded with Tertiary and Quaternary basalts and pyroclastics, and are overlain in places by the Pliocene-age Ortiz gravel deposits and Rio Grande fluvial deposits (Bjorklund and Maxwell 1961).

1.6 Soil Characteristics

According to the Bernalillo County Soil Survey (USDA 1977), soils in TA-III/V consist of the Tijeras Series. The Tijeras Series is a deep, well-drained soil formed in decomposed granitic alluvium on old alluvial fans. The surface layer is a 4-in.-thick, brown, gravelly, sandy loam. The subsoil consists of 15 in. of brown, sandy loam, with some accumulation of calcium carbonate in the lower part. Below 19 in. is a pale brown, very gravelly, loamy sand extending to a depth of 5 ft. The gravel is angular and derived from granite (USDA 1977).

The Tijeras Series is a level to gently sloping soil (0 to 5 percent) subject to moderate runoff and water erosion. Permeability is moderate, with an available water capacity of 0.10 to 0.16 in. This soil is moderately alkaline and the effective rooting depth is 5 ft deep or more (USDA 1977).

1.7 Hydrogeology

The Rio Grande flows in a southerly direction and is the primary surface drainage feature in the Albuquerque-Belen Basin. In the basin, the ground-water system is controlled by the Rio Grande and its floodplain, tributary inflow, mountain front runoff, and recharge.

The principal aquifer in the area occurs in the unconsolidated and semiconsolidated sands, gravels, silts, and clays of the Santa Fe Group. The aquifer is generally unconfined, although semiconfined conditions may exist locally because of discontinuous, lenticular silt and clay-rich deposits.

Beneath KAFB, the regional aquifer generally flows toward the Rio Grande at an average gradient of approximately 10 ft/mi; however, local perturbations in the water table exist near municipal wells and as a result of lithologic and structural controls. Prior to extensive development of the regional aquifer by the city of Albuquerque and KAFB, the predominant ground-water flow direction in the SNL/NM KAFB area was west-southwest (Bjorklund and Maxwell 1961); however, pumping by the city of Albuquerque and KAFB has substantially affected the natural ground-water flow regime (Reeder et al. 1967; Kues 1987). The production wells have a substantial effect on the hydraulic gradient in the area, creating a depression in the potentiometric surface in the northern portion of KAFB. U.S. Geological Survey (USGS) projections indicate that, by the end of the century, the water table in the Albuquerque area will drop an estimated 30 to 50 ft from 1989 levels (Reeder et al. 1967).

Major structural controls on the local flow regime are in the form of a complex assemblage of faults along the margin of the basin. These fault systems include the Manzano, Hubbell Springs, Sandia, and Tijeras faults, all of which are expressed within a zone 1.5 mi east of TA-V. The specific impact of local faulting on ground-water flow is largely unknown; however, the Tijeras and Hubbell Springs faults may control ground-water movement. It has been postulated that travertine deposition (precipitation of calcium carbonate from solution in ground water) within fault fractures has reduced permeabilities such that the faults act as barriers to ground-water movement. Springs have been observed along the fault alignments, and there is a shallow water table east of the faults. The primary regional aquifer, the valley

fill, underlies KAFB west of the Hubbell Springs fault at a depth of 400 to 600 ft and east of the fault at a depth of 50 to 150 ft (DOE 1987).

The primary source of ground water in the TA-III/V area is the unconsolidated and semiconsolidated sedimentary deposits of the basin-fill aquifer. A relatively thick unsaturated zone of approximately 460 ft overlies the Santa Fe Group deposits. The basin-fill aquifer underlying TA-III/V is recharged primarily by inflow from the mountain areas to the east. Recharge resulting from direct infiltration of precipitation is inferred to be minor because of high surface coverage, high evaporation, low precipitation, and an extensive vadose zone.

Based on water levels measured in monitoring wells near the Liquid Waste Disposal System (LWDS) in TA-V and near the Chemical Waste Landfill (CWL) and MWL in TA-III, the depth to ground water is approximately 480 to 490 ft below ground surface (bgs) in TA-III/V. Water levels measured in all wells in TA-III indicate the general ground-water flow direction is west-northwest.

2.0 SAMPLING AND ANALYSIS PROGRAM

The sampling and analysis program for the sites in TA-III/V followed standard EPA procedures for sample collection (EPA 1987a), quality assurance/quality control (QA/QC) protocols (EPA 1987b, 1980), and statistical analysis (EPA 1992a). Each of these is discussed in the following sections.

2.1 Field Methods

Field investigations at the ER sites within TA-III/V followed phased approaches according to those proposed in the RFI Work Plan (SNL/NM 1993a, 1993b), except at six sites. Field conditions dictated that methods other than those specified in the Work Plan be used at Sites 34, 36, 78, 102, 111, and 196. Deviations from the Work Plan are noted in the individual descriptions of site activities (Sections 6.0, 8.0, 11.0, 15.0, 18.0, and 21.0).

The methods of investigation used during the TA-III/V RFI included the following:

- Aerial photograph analysis and ground-truthing;
- Nonintrusive geophysical investigations;
- Radiological surveying and scrap/debris removal;
- Surface soil sampling;
- Shallow subsurface soil sampling and deep subsurface soil sampling; and
- Trenching and excavation.

Protocols for sampling and analysis at SNL/NM followed the methodologies in the ER Project Quality Assurance Project Plan (QAPjP) and Operating Procedures (OPs) developed specifically for the ER Project. A complete list of OPs used during this project is provided in Table 2-1. Although much of the field work was done before the formal issuance of the SNL/NM ER OPs, activities were conducted in accordance with generally accepted practices and professional experience and judgment (i.e., American Society for Testing and Materials [ASTM] procedures, best engineering practices, and draft OPs), which ultimately formed the basis of the final OPs. All work was conducted following the requirements of site-specific Health and Safety Plans (HASPs), which are available for review in the Environmental Operations Records Center (EORC).

The following activities were conducted at the sites noted:

- Aerial photographic interpretation—all sites;
- Geophysical surveys—Sites 26, 78, and 84;
- Radiation surveys and associated removal of radioactive anomalies—Sites 18, 83, 84, 102, 240, and 241;

Table 2-1
Sandia National Laboratories/New Mexico Environmental Restoration Project Operating Procedures Applicable to Technical Areas III and V RFI Work

Operating Procedure (OP) Number	Title
AOP 94-40	ER Project Site Posting and Security
FOP 94-01	Safety Meetings, Inspections, and Pre-Entry Briefings
FOP 94-05	Borehole Lithologic Logging
FOP 94-22	Deep Soil Gas Sampling
FOP 94-23	Hand Auger and Thin-Wall Tube Sampler
FOP 94-25	Documentation of Field Activities
FOP 94-26	General Equipment Decontamination
FOP 94-27	Thin-Walled Tube Sampling of Soils
FOP 94-28	Health and Safety Monitoring of Organic Vapors (Flame Ionization Detector [FID] and Photoionization Detector [PID])
FOP 94-30	Health and Safety Monitoring of Combustible Gas Levels
FOP 94-34	Field Sample Management and Custody
FOP 94-38	Drilling Methods and Drill Site Management
FOP 94-39	Excavating Methods
FOP 94-40	Test Pit Logging, Mapping, and Sampling
FOP 94-52	Spade and Scoop Method for Collection of Soil Samples
FOP 94-57	Decontaminating Drilling and Other Field Equipment
FOP 94-68	Field Change Control
FOP 94-69	Personnel Decontamination (Level D, C & B Protection)
FOP 94-71	Land Surveying
FOP 94-78	Environmental Restoration Project Waste Management and Characterization Procedure
FOP 94-81	Establishment and Management of Less-Than-90-Day Accumulation Areas for Environmental Restoration Project Sites
FOP 95-23	Shallow Subsurface Drilling and Soil Sampling Using Mechanized Hydraulic Augers or the Geoprobe® Soil Core Sampler

Source: SNL/NM (1995a).

- Sampling of surface soils—Sites 18, 31, 35, 78, 107, 240, and 241;
- Subsurface sampling using augers, a hydraulic probe, or a full-size drill rig—Sites 18, 34, 35, 36, 37, 78, and 111;
- Trenching, excavation, and other cleaning—Sites 51, 78, 100, 102, 196, and 241; and
- Voluntary removal actions or cleanups (excluding the radiological removals)—Site 78.

Further investigation of Sites 26, 83, 84, and 240 (active sites) will be postponed until site decommissioning in the future. Site 26 is proposed in this RFI report (Section 4.0) to be combined with Site 83 for future investigation. No schedule for decommissioning or corrective action at these sites has been identified at this time.

Two VCMs were conducted during the course of the RFI. One was performed to survey and remove radiological constituents at the six sites listed above; details of this VCM are provided in Section 24.0. The second was performed at Site 78 to remove gas cylinders and mitigate health and safety hazards; the details of this VCM are provided in Section 11.0.

Subsurface and ground-water investigations conducted at the neighboring LWDS in TA-V are detailed in the RFI report submitted for that site in September 1995 (SNL/NM 1995b). Because no ground-water investigations were conducted during the TA-III/V RFI, the LWDS RFI report should be consulted for information on this subject. Reports on the ongoing investigation at the CWL in TA-III also should be consulted for ground-water information.

2.1.1 Aerial Photograph Analysis and Ground-Truthing

An examination of aerial photographs was conducted to locate possible additional ER sites within TA-III/V and to gather supplemental data on existing sites. Aerial photographs from 1973 to 1990 were assembled and digitized using an Arc/Info Geographic Information System (GIS) and were used to produce a set of year-specific overlays. A base photographic image was combined with the year-specific overlays to illustrate the changes in surface features over time (Plate I). All of the sites were evaluated within 1,000 ft of the site boundaries (unless noted otherwise) for signs of soil disturbance, vegetation changes, or new construction. Surface features were grouped into eight categories including cleared or disturbed surface, concrete pad, landfill, pile, possible excavation, tank/concrete target, trench, and unknown. An attempt was made to further subcategorize features, but no additional or valuable information was revealed.

After the aerial photograph interpretation was completed, ground-truthing (field verification) was performed to determine whether the interpretations were valid. Field personnel inspected the suspect areas for evidence of potential site impacts; e.g., cleared or disturbed surfaces were located to within 10 ft of the area seen on the photographs and were examined for signs of burning, scraping, or blading for road or facility construction, and were validated as such. In a few instances, revegetation and cultural activities did not permit the unequivocal verification of features identified in early photographs. Site-specific discussions of the aerial photograph interpretation are included in each site section.

2.1.2 Nonintrusive Geophysical Investigations

Nonintrusive electromagnetic (EM) conductivity (metal detection) and vertical-gradient magnetometer surveys were conducted at ER Sites 26, 78, and 84 to locate any potential subsurface objects. The sites were gridded to detect objects of a certain size and are listed below.

- Site 26, Northern Portion—Locate and map any objects equivalent to or larger than two 55-gallon (gal.) drums buried at a depth of 5 ft.
- Site 26, Southern Portion—Locate and map any objects equivalent to or larger than one 55-gal. drum buried at a depth of 5 ft.
- Site 78—Locate and map subsurface concentrations of metal, particularly cylinders with dimensions of 12 in. by 2 in.
- Site 84—Locate major fragments of depleted uranium (DU), lead, and metallic materials larger than 3 in. by 3 in. buried to a depth of 1.5 ft; and significant burials equivalent to a 5-gal. bucket buried to a depth of 3 ft.

Wooden stakes and plastic pin flags were used to delineate the traverse spacings. Electromagnetic data were gathered using a Geonics Ltd.™ EM-61 high-precision metal detector; magnetic data were gathered using a Geometrics™ G-856-AX proton precession magnetometer deployed in the vertical mode. A brief description of each follows.

The EM-61 generates EM pulses by passing a current through a 1-square-meter (m^2) coil. These pulses penetrate the subsurface and briefly induce secondary EM fields; soil has relatively low conductivity, and the secondary fields dissipate rapidly. Buried metallic objects have essentially infinite conductivity when compared to soil, and their secondary fields persist much longer. The EM-61 measures the strength of the secondary fields during the "off time" between the primary pulses. The measurement is delayed until the response from the soil has dissipated and only the response of buried metal is present. The secondary EM fields are measured by a 1-m^2 main sensor which is coincident with the transmitter coil, and by a second focusing coil positioned 40 centimeters (cm) above the main coil. Each sensor coil measures the secondary field strength during a time period between the primary pulses. Two sensor coils are used to allow differentiation between shallow objects and deeper objects. The EM-61 was deployed in the trailer mode, towed on wheels behind the operator, with data acquisition triggered by the wheel approximately every 20 cm.

The G-856-AX consists of two magnetic sensors mounted on the same vertical staff separated by a known distance. The instrument generates a pulse and registers the difference in time for the return magnetic pulse to be recorded by the top and bottom sensors. This difference is then converted to a standard reading. The G-856-AX was held vertically, and moved along the traverse manually, from grid node to grid node. Data acquisition was performed manually or programmed to be collected at regular intervals (every few seconds [sec]).

2.1.3 Surface Radiological Survey and Scrap/Debris Removal

Nonintrusive surface radiological surveys were performed at 64 sites at SNL/NM including six sites within TA-III/V, as part of a coordinated facility-wide assessment and removal VCM. Surveys were conducted in a manual sweep pattern using a line of five to six 2-in. by 2-in. sodium iodide (NaI) detectors optimized to detect DU. Gridded areas were surveyed by technicians in straight traverses, each covering a 6-ft-wide swath.

A list of radioactive anomalies (both point and area sources) at each site was compiled. After the surveys were complete, all the point sources and the majority of the area sources were removed by hand and placed in a container. Subsequent to the removal action, soil samples were collected to confirm effective cleanup. Brief discussions of results are included in the individual site sections, and a more detailed description of the radiological surveys conducted at the sites within TA-III/V that were suspected of exhibiting radioactive soil contamination is provided in Section 24.0.

2.1.4 Surface Soil Sampling

Surface soil samples were collected from a depth of 0 to 1 ft bgs using a stainless-steel trowel and bowl. All sampling equipment was cleaned between samples using dry decontamination methods (i.e., paper towels, brushing, etc.) where possible or rinsed with distilled water. Sample location coordinates are provided in Appendix A.

2.1.5 Shallow Subsurface Soil Sampling

Shallow subsurface soil sampling was accomplished using either hand or power augers or a small-diameter hydraulic probe. Discussions of these techniques follow.

Auger Sampling

Augering using a hand bucket or power auger and thin-walled stainless-steel samplers was generally performed at sites where sampling depth was a maximum of 10 ft bgs. Soil augering was performed to a predetermined depth approximately 6 in. above the level to be sampled, and the bucket auger was extracted. Loose soil was removed, and a separate sampling auger was used to collect the sample. All augering and sampling equipment was cleaned between sample locations using dry decontamination methods where possible or rinsed with distilled water.

Small-Diameter Boring

At sites where augering techniques would not attain the desired depths (generally greater than 10 ft bgs), a vehicle-mounted, hydraulically powered soil probing machine that uses static force and a percussion hammer was utilized to advance small-diameter sampling tools into the subsurface to collect soil samples to 30 ft bgs. The unit used was manufactured by Geoprobe™. The probe produced no drill cuttings and obtained samples through probe holes of 1 to 1.5 in. diameter with typical penetration rates of 1 to 2 ft per minute.

Small quantities of soil were obtained by driving the probe to a predetermined depth, disengaging an expendable drive point at the target depth and pulling back 3 to 6 in. on the probe rods, and then redriving the hollow rods. The end of the rod was filled with soil cut from the wall of the hole.

2.1.6 Deep Subsurface Sampling

Drilling was conducted at Site 36 using an air rotary casing hammer rig to drill to depths of greater than 300 ft bgs. A more detailed discussion of the drilling and sampling procedures used at the site is included with the Site 36 activity description in Section 8.0.

2.1.7 Excavation and Trenching

Excavation, trenching, and cleanouts were accomplished using a backhoe, trackhoe, clamshell, or front-end loader at several sites. Details of the excavations and cleanouts are provided in the individual site sections for Sites 51, 78, 100, 102, 196, and 241.

2.2 Field Screening and On-Site Laboratory Analysis Methods

Where feasible, field screening was conducted on approximately 100 percent of the collected soil samples from all sites investigated in TA-III/V. At least 20 percent of these were submitted for confirmatory analysis at an EPA-approved Contract Laboratory Program (CLP) laboratory (Section 2.3). The field screening data for each site are included in Appendix B. Discussions of the following field-screening methods used during the RFI are included in subsequent sections:

- Photoionization detection (PID) and flame ionization detection (FID) of volatile organic compounds (VOCs);
- Soil vapor detection of VOCs;
- Thermal desorption detection of mineral oil;
- Immunoassay detection of polychlorinated biphenyls (PCBs) and high explosives (HEs);
- X-ray fluorescence (XRF) analysis of metals;
- Direct current plasma (DCP) and inductively coupled plasma (ICP) analysis of metals; and
- Gamma spectroscopic analysis of radionuclides.

2.2.1 Photoionization Detection and Flame Ionization Detection of Volatile Organic Compounds

Screening for VOCs in the field was generally accomplished using hand-held PIDs and FIDs. The units used were manufactured by HNU and Foxboro. Soil samples were placed in a glass jar, sealed, agitated, and warmed to allow volatile constituents to develop in the headspace of the jar. The PID or FID sample probe was placed in the headspace, where a sample of vapor was drawn into a chamber, ionized, and interpreted by the instrument. The low sample rate allowed for only very localized readings. Monitoring for health and safety levels was also performed during drilling activities at 5-ft intervals downhole, as well as in the breathing zone. Where elevated organic vapor levels were encountered, monitoring was

performed continuously in the breathing zone. The instrument calibrations and readings were recorded in the field logbook.

2.2.2 Soil Vapor Analysis

Soil samples were collected for on-site analysis of soil vapor for the presence of VOCs during drilling activities at Site 36 and were immediately transported to the TA-III ER Field Laboratory for analysis. Soil vapors were collected by polyethylene tubing connected to a glass bulb using a pump under vacuum.

Soil vapor analyses were conducted by purging a 500-milliliter (mL) gas bulb for 20 minutes (min) with helium onto a trap and desorbing the trap onto a gas chromatograph equipped with a mass selective detector (MSD). Purging the entire contents of the sample bulb allowed attainment of lower detection levels for the sensitive soil vapor analysis. All analyses were performed on an HP 5972 MSD with an HP 5890 Series II plus gas chromatograph. EPA Methods 8240/8260 (EPA 1986) procedures were used for calibration and quantitation. The target analyte list (TAL) for EPA Method 8240 was used. For heavily contaminated soils, a smaller aliquot of gas was subsampled from the 500-mL bulb.

2.2.3 Thermal Desorption/Gas Chromatography

SNL/NM ER personnel conducted an investigation of available technologies to locate an alternative heavy-end total petroleum hydrocarbon (TPH) field-screening technique that was more reliable than the Hanby Method. Neither the Hanby Method nor field screening using immunoassay kits was effective because neither is sensitive to the nonaromatic High Energy Radiation Megavolt Electron Source (HERMES) transformer oil (discussed below). As a response to these ineffective screening methods, SNL/NM developed a technique that employs thermal desorption/gas chromatography (TD/GC) to rapidly quantify non-PCB-containing transformer oil in soil.

The transformer oil used at the HERMES-II facility is primarily a mixture of aliphatic and alicyclic hydrocarbons, and contains no significant quantities of EPA-regulated hazardous constituents as manufactured (e.g., PCBs or VOCs). Indeed, any appreciable amount of VOCs in the dielectric oil would have significantly altered the insulating properties of the oil. The boiling point for the mineral oil ranges from approximately 120 degrees Celsius (°C) to 365°C; its relatively low volatility makes it undetectable by real-time field monitoring instruments such as PIDs and FIDs, which rely on volatilization of contaminants at ambient conditions.

TD/GC has been used to characterize fuel-contaminated soils (i.e., those containing volatile and/or semivolatile constituents) and soils containing PCBs (Goldsmith 1994). The technique utilizes the direct injection of organic contaminants from soil onto a GC column, avoiding the use of environmentally harmful solvents. The method detection limit (MDL) is 10 milligrams per kilogram (mg/kg). The low MDL is a result of direct sample analysis without the potential dilution problems associated with sample preparation. Method sensitivity is also enhanced by analysis of the soil sample within hours of field collection, which minimizes potential storage loss and cross-contamination.

TD/GC analyses for mineral oil were performed using an SRI Model 8610 GC equipped with a TD oven and a manual sampling valve. The system was equipped with an FID that was used for the detection and quantitation of the oil after it had passed through the TD/GC sequence. An aliquot of soil

(approximately 1.0 gram [g]) was placed in the desorption chamber for 1 min at 325°C to vaporize organic constituents. The vapors were then swept onto the GC column for separation. A relatively nonpolar megabore capillary column (J&W Scientific, DB-5, 8 ft by 0.53 millimeter [mm]) was used for constituent separation and quantitation. A five-point calibration curve was generated by spiking clean sand with a mixture of HERMES oil in toluene (10 to 500 mg/kg). The curve was linear with a correlation coefficient of $r^2 = 0.998$. TPH in soil was quantified by "pattern recognition" using the total area under the distinctive mineral oil chromatogram. An external standard (dodecane) was added to determine sample matrix interference and injection efficacy. QA samples included replicate analyses for every 10 samples and a mid-range calibration check standard prior to daily sample analyses, after every 20 samples, or at the end of a 12-hour (hr) period.

2.2.4 Immunoassay Tests for Polychlorinated Biphenyls and High Explosives

Immunoassay tests for chemical constituents are based on the antibody response of mammalian immune systems to the introduction of chemical contaminants. To produce the desired antibodies in the kit, predetermined concentrations of specific chemicals are introduced into a test animal, causing the animal's immune system to produce antibodies to that chemical. Antibodies are extracted, separated, purified, and encapsulated for test kits. The antibodies in the test kits respond to varying concentrations of chemical compounds by giving varying responses. The test kits for PCBs and HEs, both manufactured by EnSys Inc., are discussed below.

PCBs

The protocol for PCB test kits conforms to SW-4020, immunoassay-based field screening for PCBs in soil. Detection limits range from 400 microgram per kilogram (µg/kg) for Aroclors 1254 and 1260 (prevalent Aroclors in dielectric fluids at SNL/NM) to 1, 2, 4, and 4 mg/kg for Aroclors 1248, 1242, 1016, and 1232, respectively. The test is specific to PCBs and has no anticipated interferences. The field test is positively biased for PCBs. Rigorous testing against lab-GC SW-8080 (prior to commercial availability of the test kit) resulted in false negatives in less than 1 percent of field tests performed. When testing samples, the method requires standard replicate analysis with each environmental sample analyzed; the relative standard deviation must be within ±20 percent, or the sample analysis will be repeated.

HEs

The field test kit for HE conforms to proposed SW-8515 for field screening for trinitrotoluene (TNT) in soil and can detect TNT, dinitrotoluene (DNT) isomers, and trinitrobenzene at concentrations of approximately 1 mg/kg in soil as measured by colorimetric reaction. The test is positively biased for HEs. Prior to commercialization of the test kit, false negatives were identified by SW-8515 in less than one percent of the field samples.

2.2.5 X-Ray Fluorescence

XRF was conducted using a Spectrace® 6000 Spectrometer. XRF is a whole-rock quantitation method for analyzing concentrations of elemental metals in environmental samples. Characteristic X-ray spectra are emitted when a specimen is irradiated with a beam of sufficiently short wavelength X-radiation. Standard reference materials of the National Institute of Standards and Testing (NIST) are used to verify the accuracy of the calibration. XRF can analyze metals with detection limits of 10 to 60 mg/kg. XRF is

a nondestructive method for analyzing environmental samples and generates no waste; samples are dried and ground prior to analysis. XRF was used during sampling activities as a field-screening tool for metals to direct the sampling for off-site laboratory analyses.

2.2.6 Direct Current Plasma/Inductively-Coupled Plasma

DCP and ICP elemental analyses for metals concentrations were conducted in accordance with SW-6010A using a Leeman PS 1000 sequential ICP. Soil samples were prepared by microwave-assisted acid digestion (EPA Methods 3051 and 6010 QA requirements). An aerosolized sample is introduced into a plasma of argon gas, producing characteristic spectra.

2.2.7 Mercury Analysis

Soil samples were analyzed for mercury content following EPA SW-7471A, "Mercury in Solid or Semisolid Waste (Manual Cold-Vapor Technique)" (EPA 1994). The instruments used were a Leeman AP200 Automated Mercury Preparation System and a Leeman PS200 Automated Mercury Analyzer. A 0.1-g aliquot of soil was used for sample preparation and analysis. The practical limit of quantitation (PLQ) was 0.3 µg/kg.

2.2.8 Gamma Spectroscopy

All soil samples collected from areas suspected to be impacted by radioactive compounds were screened for radiological constituents using gamma spectroscopy. In some instances, these screens were mandatory to allow samples to be shipped to an off-site laboratory for chemical analysis. In other cases, the only analysis of the samples was the gamma spectroscopy.

Soil samples were collected in 500-mL Marinelli beakers, sealed, swiped, and counted in the field for loose, surface, radioactive contamination. Upon completion of the field check, the samples were transported to the SNL/NM 7715 laboratory for fixed gamma spectroscopic analysis.

The equipment used by the SNL/NM 7715 laboratory consists of a Canberra high purity germanium (HPGE) detector shielded by 4 in. of lead lined with cadmium and copper sheets. Twelve samples in Marinelli beakers can be run unattended using an autosampler. A typical sample is counted for 600 sec. Peaks generated during the gamma spectroscopy are matched against a user-defined library to identify individual radionuclides. Laboratory control sample (LCS) analyses are performed for americium-241, cesium-137, and cobalt-60 with identical analytical methods to monitor routine sample analysis data usability.

2.3 Off-Site Laboratory Chemical Analyses

Off-site laboratory analyses for constituents of concern (COCs) from each site were conducted in accordance with the EPA-approved protocols listed in SW-846 (EPA 1986). The COCs, field-screening techniques, laboratory analysis methods, and the corresponding method numbers are listed in Table 2-2. The data are provided in electronic format in Appendix C.

Table 2-2
Field Screening and Laboratory Analyses for Constituents of Concern[a]

Constituent of Concern	Field-Screening Techniques	On-Site Laboratory Analysis Methods	Off-Site Laboratory Analysis Methods	EPA Method Number
Metals	NA[a]	X-ray Fluorescence/ Directly Coupled Plasma	Inductively Coupled Plasma/Atomic Absorption	6010/7000
Volatile Organic Compounds (VOCs)	Photoionization Detector/ Flame Ionization Detector	Gas Chromatography/ Mass Spectrometry	Gas Chromatography/ Mass Spectrometry/ Toxicity Characteristic Leaching Procedure	8240 1311
Total Petroleum Hydrocarbons (TPH)	NA	Thermal Desorption/Gas Chromatography	Infrared	418.1
High Explosives (HEs)	Colorimetry	High-Performance Liquid Chromatography	High-Performance Liquid Chromatography	8330
Polychlorinated Biphenyls (PCBs)	Immunoassay	NA	Gas Chromatography	8080
Nitrates/Nitrites	NA	Colorimetry	Colorimetry	353.2
Radionuclides	G-M Pancake Probe/Sodium Iodide (NaI) Scintillometer	Gamma Spectroscopy	Gamma Spectroscopy/ Isotopic Analyses	6010

Source: EPA 1986.

[a]NA = Not applicable.

2.4 Summary of Quality Assurance/Quality Control Activities

As part of the sampling activities conducted in support of the RFI, a plan for QA/QC was developed to ensure that sampling procedures and laboratory analyses were performed to a rigid standard. The following QA/QC soil and water samples were collected to assure sampling procedure integrity and laboratory quality:

- Field Blank—Water poured directly from a freshly opened bottle of distilled water into laboratory-prepared sample bottles to determine whether any field conditions affected sample collection.

- Trip Blank—Laboratory-prepared water sample for analysis of VOCs to determine whether any VOCs were inadvertently introduced during sampling or shipment.

- Equipment Blank—Water sample prepared in the field after decontaminating equipment to determine whether any contaminants were introduced from improperly cleaned equipment.

- Duplicate—Soil sample split from an original field sample to determine reproducibility of laboratory analytical results.

- Matrix Spike/Matrix Spike Duplicate—Soil sample split from an original field sample to determine effects of matrix (e.g., soil) on laboratory results (i.e., whether any interference occurred); sample is spiked with a known concentration of a reference chemical, then analyzed to ascertain recovery of that chemical.

Results of the QA/QC program indicated very few problems with the collection of the data. Some general trends in laboratory QC were noted. The off-site laboratory used for the chemical analyses has consistently shown levels of VOCs (primarily acetone and methylene chloride) in their method blanks; however, this mainly impacted the data collected for Site 36, where elevated levels of several VOCs were noted (see Section 8.0). Independent analyses conducted by the on-site SNL/NM laboratory confirmed the presence of contamination in the samples, however, so the impact of laboratory contamination is somewhat lessened.

Some elevated levels of VOCs were noted in some soil trip blanks submitted for Site 78. Preparation of the soil trip blanks involved collection of soil from an area known to be uncontaminated, followed by heating of the sample to drive off any potential VOCs, which effectively removed any moisture that might have been in the sample. It is believed that, because the sample was dehydrated, when it reached the laboratory, the ambient humidity and vapor-phase VOCs typical of many laboratories (i.e., those VOCs commonly used for sample preparation [acetone, methylene chloride, toluene, etc.]) caused rapid adsorption of the laboratory chemicals onto the soil matrix, producing erroneous results. The process for preparing soil blanks on-site is currently under review, because it does not appear to be a useful tool in its present form, given the problems cited above. Regardless of the results of the trip blanks for Site 78, no elevated VOCs were noted in the soil samples collected for confirmatory analyses.

The same laboratory exhibited low concentrations of lead in their blanks, affecting the data for the rinsate and field blanks from Sites 18 and 107, but at concentrations too low to account for the concentrations detected above the statistical background levels for Site 18.

Matrix spike/matrix spike duplicate (ms/msd) data indicated occasional elevated recoveries for some metals (antimony, barium, beryllium, and zinc) that are ubiquitous in the surrounding granite-derived soils. No general problems with the laboratory's recovery were noted, however. The single exception is for the ms/msd data for antimony at Site 241. Because of apparent erroneous recovery data, the sample that had been split for a ms/msd had an anomalously high antimony concentration (29.6 mg/kg). The location (plus two others) was resampled and found to have nondetectable antimony. The results of the QA/QC program are provided in electronic format in Appendix D.

2.5 Statistical Analysis of Background Data

To determine whether the soil sampling results for potentially contaminated sites within TA-III/V indicated the presence of COCs, the results were compared to the samples collected from TA-III and TA-V during the site-wide investigation of background concentrations at SNL/NM (IT 1994a). Thus, a subset of the full site-wide background data set was selected for the TA-III/V evaluation. The COCs for

evaluation (barium, beryllium, cadmium, chromium, copper, lead, nickel, silver, uranium, and zinc) were chosen based on site knowledge and their likelihood of being a site contaminant within TA-III/V. At the time the statistical tests were completed, no site-wide background data sets existed for other COCs of interest (e.g., antimony, mercury, PCBs, etc.); thus a direct comparison to the applicable site-wide upper tolerance limits (UTLs, discussed below) updated in January 1996 was made for those COCs.

2.5.1 Background Concentration Determinations

To determine the range of background concentrations, the 95th UTL and 95th percentile were calculated for parametric and nonparametric data sets, respectively. The following steps were completed: (1) a priori screening of the data; (2) determination of the percentage of nondetects in the data sets, with a cutoff level of 15 percent; (3) distribution analysis of the portion of the data set that exhibited less than 15 percent nondetects, including coefficients of skewness, histograms, and probability plots; (4) a second screening of the data performed by the calculation of the T_n statistic for parametric data; and finally (5) calculation of the UTL for parametric data sets or the 95th percentile for nonparametric data sets. Each is discussed in the following sections, and example calculations, together with histograms and probability plots, are provided in Appendix E.

A Priori Screening

The a priori test involved a visual inspection of the data to eliminate any outliers. The data values were sorted from highest to lowest to facilitate the inspection. Maximum values that were a factor of three higher than their nearest neighbor were removed from the data set before the next test in the sequence was applied.

Determination of Parametric Versus Nonparametric Data

The data sets were divided into parametric or nonparametric by this process (discussed in the following paragraphs):

- Initial division based on the percentage of nondetect data; and
- Subdivision of the data sets with fewer than 15 percent nondetect values into normal, lognormal, or nonparametric.

First, the percentage of nondetect data in each of the data sets was determined. Raw nondetect data were not equated with "zero" values; rather, they were replaced with a coded value of one-half of the PLQ (EPA 1992a). Those sets with fewer than 15 percent nondetect values were identified as eligible for parametric distribution analysis; those sets with greater than 15 percent nondetect values were identified as eligible for nonparametric analysis. Coded data sets tend to skew the data toward zero and decrease the effectiveness of reporting the mean. Therefore, the median is reported as the measure of central tendency when greater than 15 percent of the data are nondetects (i.e., the data set appears nonparametric).

Distribution analyses then were conducted on the data to determine whether the data were parametric (normal or lognormal) or nonparametric. The distribution analyses included computing the coefficients of skewness and producing the histograms and probability plots for each COC for normal and lognormal (i.e., log transformed) data; the histograms and probability plots for each tested COC are included in Appendix E.

Calculation of T_n Statistic

The T_n statistic test was performed on data determined to be parametric (normal or lognormal) after the distribution analysis was completed to verify that no other statistical outliers existed. The datum was considered an outlier if the T_n statistic exceeded the critical number (C_n) identified in the EPA guidance for a given sample size (EPA 1992a). The test was run iteratively until the largest value in the data set passed. A new mean and standard deviation were calculated for each data set that had outliers removed in the T_n statistic analysis before the test was run again.

Calculation of UTL and 95th Percentile

Basic statistical parameters, including the mean, standard deviation, and UTL, were calculated for each normal or lognormal parametric population data set. The UTL establishes a concentration range that is constructed to contain a specified proportion of the population with a specified confidence. The proportion of the population included is referred to as the coverage, and the probability with which the tolerance interval includes the proportion is referred to as the tolerance coefficient. The EPA-recommended coverage value of 95 percent and tolerance coefficient value of 95 percent were used to calculate the UTLs (EPA 1992a). Most elementary statistical textbooks provide detailed descriptions of basic parametric statistics.

Nonparametric statistics were used when data sets did not exhibit normal or lognormal distributions, or when the percentage of nondetects exceeded 15 percent. The data sets examined exhibited fewer than 90 percent nondetects, so the median (50th percentile) was used to describe central tendency, and the 95th percentile was used for background comparison. Most elementary statistical textbooks provide detailed descriptions of basic nonparametric statistics.

Results

Table 2-3 presents the results of the a priori tests conducted on the data sets. None of the COCs examined were determined a priori to be outliers.

Table 2-4 provides the results of the probability plot, coefficient of skewness, and histogram for determination of the distribution type for each TA-III/V background data set. Background distributions for barium, beryllium, cadmium, copper, lead, nickel, and zinc were lognormal. The data set for silver was nonparametric, and the data set for total uranium (U_{tot}) was normally distributed.

Tests were performed for outliers using the T_n statistic (Table 2-5). Only the nickel data set was censored for the calculation of TA-III/V background values by removing the three highest values for nickel (30.9, 30.0, and 29.5 mg/kg. Three possible reasons for the anomalously high nickel data are noted. Nickel might exhibit a wide natural variation, and this sampling effort happened to access areas that were relatively mineral rich. Alternatively, laboratory error might have produced elevated analytical results. It is also possible that the higher nickel concentrations are anthropogenic, although these higher concentrations are well below the proposed RCRA Subpart S soil action level for nickel (2,000 mg/kg). To be conservative, these values were removed from the data set, and the censored data set was used for all subsequent comparisons for TA-III/V sites.

The natural logs of the means and standard deviations of the TAL metals and their corresponding UTLs or 95th percentiles are provided in Table 2-6. Proposed RCRA Subpart S soil action levels for the COCs detected during the RFI sampling effort are provided in Table 2-7. As stated earlier, only those COCs

Table 2-3
Technical Areas III and V Background Samples - A Priori Sampling

Parameter	Maximum Value	Next Maximum	X Factor[a]	Result
Barium	730	320	2.28	Pass
Beryllium	1.1	1.1	1.00	Pass
Cadmium	8.5	7.7	1.10	Pass
Chromium	58.1	57.3	1.01	Pass
Copper	29	27.5	1.05	Pass
Lead	73	73	1.00	Pass
Nickel	30.9	30	1.03	Pass
Silver	10	9.7	1.03	Pass
Uranium (total)	4.66	4.61	1.01	Pass
Zinc	59.9	56	1.07	Pass

[a]X factor is the ratio of the maximum value to the next maximum. If the ratio is greater than or equal to 3, it indicates the maximum value is anomalously high.

Table 2-4
Results of the Distribution Analysis for Technical Areas III and V

Parameter	Probability Plot	Coefficient of Skewness[a]	Histogram	Distribution Type
Barium	Lognormal	-2.3	Lognormal	Lognormal
Beryllium	Lognormal	-0.30	Lognormal	Lognormal
Cadmium	Lognormal	0.49	Lognormal	Lognormal
Chromium	Lognormal	-1.72	Lognormal	Lognormal
Copper	Lognormal	-0.15	Lognormal	Lognormal
Lead	Lognormal	0.50	Lognormal	Lognormal
Nickel	Lognormal	-0.48	Lognormal	Lognormal
Silver	Nonparametric	-0.59	Nonparametric	Nonparametric
Uranium (total)	Normal	-0.23	Lognormal	Normal
Zinc	Lognormal	0.69	Lognormal	Lognormal

[a]Critical Coefficient of Skewness is -1 to 1.

Table 2-5
Technical Areas III and V T_n Statistic Analysis for Target Analyte List Metals

Parameter	Distribution	Natural Log (Ln) of Maximum Value	Natural Log Mean	Natural Log Standard Deviation	T_n Statistic	Number of Samples	Critical Value[a]	Pass or Fail T_n Statistic
Barium	Lognormal	6.59	3.84	1.13	2.44	503	3.74	Pass
Beryllium	Lognormal	0.10	-1.14	0.43	2.87	331	3.60	Pass
Cadmium	Lognormal	2.14	-0.89	0.99	3.06	176	3.39	Pass
Chromium	Lognormal	4.06	1.86	0.8	2.75	538	3.76	Pass
Copper	Lognormal	3.37	1.82	0.48	3.22	392	3.66	Pass
Lead	Lognormal	4.29	1.89	0.73	3.29	259	3.52	Pass
Nickel (first iteration)	Lognormal	3.43	1.84	0.43	3.70	403	3.67	Fail
Nickel (second iteration)	Lognormal	3.40	1.83	0.42	3.74	402	3.67	Fail
Nickel (third iteration)	Lognormal	3.38	1.83	0.42	3.70	401	3.67	Fail
Nickel (fourth iteration)	Lognormal	3.31	1.83	0.41	3.62	400	3.67	Pass
Silver	Nonparametric	ND[b]	ND	ND	ND	247	ND	ND
Uranium (total)	Normal	4.66[c]	2.05[c]	0.99[c]	2.64	81	3.13	Pass
Zinc	Lognormal	4.09	3.1	0.34	2.89	158	3.36	Pass

[a]One-sided critical values for the upper 5 percent significance level; critical values derived from Table 8 (EPA 1992a) for given number of samples.
[b]ND = Not determined.
[c]Normal maximum values (i.e., actual values) provided for normally distributed uranium.

Table 2-6
Upper Tolerance Limits for Target Analyte List Metals in Technical Areas III and V Soil

Target Analyte List (TAL) Metal	Distribution	Censored?	Natural Log Mean	Natural Log Standard Deviation	Mean	Standard Deviation	One-Sided Tolerance Factor (K)	Natural Log UTL	UTL	Number of Samples
Barium	Lognormal	No	3.84	1.13	NA[a]	NA	1.76	5.83	341.0	503
Beryllium	Lognormal	No	-1.14	0.43	NA	NA	1.79	-0.37	0.7	331
Cadmium	Lognormal	No	-0.89	0.99	NA	NA	1.85	0.94	2.6	176
Chromium	Lognormal	No	1.86	0.8	NA	NA	1.76	3.27	26.2	538
Copper	Lognormal	No	1.82	0.48	NA	NA	1.78	2.67	14.5	392
Lead	Lognormal	No	1.89	0.73	NA	NA	1.81	3.21	24.8	259
Nickel	Lognormal	Yes	1.83	0.4	NA	NA	1.78	4.40	81.3	400
Silver[a]	Nonparametric	NA	NA	NA	NA	NA	NA	NA	NA	247
Uranium (total)	Normal	No	NA	NA	2.05	0.99	1.96	NA	4.0	81
Zinc	Lognormal	No	3.1	0.34	NA	NA	1.86	3.73	41.8	158

[a]NA = Not applicable.
[b]For silver, the 50th percentile value was 1 mg/kg and the 95th percentile value was 4 mg/kg; these describe the central tendency for nonparametrically distributed parameters.

Table 2-7
Generic Proposed Soil Action Levels Under Proposed RCRA Subpart S

Analyte	Proposed RCRA Subpart S Soil Action Level (mg/kg)
1,2-Dichloroethane	8
Acetone	8,000
Aluminum	NA[a]
Antimony	30
Arsenic	20
Barium	6,000
Beryllium	0.2
Bis (2-Ethylhexyl) Phthalate	50
2-Butanone	50,000
Cadmium	80
Calcium	NA
Chromium (VI)	400
Cobalt	NA
Copper	NA
2-Hexanone	NA
Iron	NA
Lead	2,000[b]
Lithium	NA
Magnesium	NA
Manganese	NA
Mercury	20
Nickel	2,000
Nitrate	100,000
Nitrite	8,000
Polychlorinated Biphenyls	0.1
Potassium	NA
Selenium	400
Silver	400
Sodium	NA
Toluene	20,000
Total Petroleum Hydrocarbon	100[c]
Uranium	NA
Vanadium	600
Xylenes (total)	200,000
Zinc	20,000

[a]NA = No proposed RCRA Subpart S soil action level is currently listed for the analyte.
[b]Lead action level not formally promulgated; proposed 2,000 mg/kg (EPA 1996).
[c]Not EPA-regulated. Standard from New Mexico Environmental Improvement Board Underground Storage Tank Regulations (NMEIB/USTR 1990).

for which site-wide background data sets existed (at the time of this RFI) were analyzed for statistical significance. The proposed RCRA Subpart S soil action levels for the remaining COCs are provided for comparison to site sampling data.

2.5.2 Comparison Tests: Background Data Versus Environmental Restoration Site Data

Two nonparametric, two parametric tests, and one test that utilized both parametric and nonparametric analyses were used to compare TA-III/V background data to data from potentially contaminated TA-III/V ER sites (Appendix E). The nonparametric tests included the Wilcoxon Rank Sum (WRS) Test and the Quantile test. The parametric tests included Student's t-tests using assumptions of equal and of unequal variance. The hot-measurement comparison uses either the 95th UTL calculation (for parametric data) or the 95th percentile calculation (in the case of nonparametric data) as recommended by the EPA (EPA 1992a). Nonparametric tests were applied to all soil data; however, parametric tests were not applied to nonparametric data.

The WRS test is performed by ordering all observations from background and the potentially contaminated site according to their magnitude and then assigning a rank from lowest to highest. The ranks in the potentially contaminated area are summed and compared to a table of critical values to determine whether the site is contaminated.

The WRS test is a nonparametric test more powerful than the Quantile test (described below) in determining whether the potentially contaminated area has concentrations uniformly higher than background (EPA 1992a). However, the WRS test allows for fewer less-than measurements than the Quantile test. As a general rule, the WRS test should be avoided if more than 40 percent of the measurements taken at the potentially contaminated area or at background areas are nondetects. All soil analytical data were subjected to the WRS test in this analysis, although the test power was known to be greatly reduced when the nondetect percent was greater than 40.

The Quantile test is performed by separating background data and individual site data. The data are then ordered from highest to lowest. The number of background and individual site data points are calculated. The number of data points for background and the selected potentially contaminated site is then compared to a table that identifies how many of the highest measurements must come from the potentially contaminated site versus background to indicate contamination.

The Quantile test is a nonparametric test that has more power than the WRS test to detect when only a small portion of the remediated site has not been completely cleaned up. Also, the Quantile test can be used even when a fairly large proportion of the measurements is below the limit of detection (EPA 1992a).

The hot-measurement comparison consists of comparing each measurement from the potentially contaminated area with an upper-limit concentration value. This upper-limit concentration value is such that any measurement from the potentially contaminated area that is equal to or greater than this value indicates an area of relatively high concentrations that must be further investigated (EPA 1992a). Concentrations exceeding the upper-limit value may indicate inappropriate sample collection, handling, or analysis procedures, or actual contamination. The upper-limit concentration value was calculated as previously described based on the 95th percentile for nonparametric data and the 95th UTL for parametric data.

The t-test is a parametric test that compares the means of two samples. To use the t-test statistic, both sampled populations must be approximately normally (or lognormally) distributed with approximately equal population variances, and the random samples must be selected independently of each other. The equations and methodology for applying the t-test are explained in most statistics books, including McClave and Dietrich (1982) and Mendenhall (1975).

Results

Comparison tests between background data and the maximum concentrations for TA-III/V site data were performed for metals at Sites 18, 51, 107, 111, 240, and 241 in accordance with the RFI Work Plan (SNL/NM 1993a). In the case of Site 78, a simple comparison of maximum metal concentrations to the TA-III/V background UTLs were made for the samples collected during the confirmatory sampling event. These were the only sites where metals were regarded as suspect contamination. The respective text sections herein contain discussions of the significance of the statistical tests on data for each site and comparisons to the relevant proposed RCRA Subpart S soil action levels (Table 2-7) for each constituent.

2.6 Contaminant Fate and Transport/Risk Assessment

The majority of contaminants detected at sites in TA-III/V were restricted to the upper 2 ft of surface soils. No conclusive evidence has been found that any sites investigated during this RFI have had an impact on the local ground water (at depths of 480 to 500 ft bgs).

For those sites at which contaminants were elevated with respect to background, a comparison was made of each elevated constituent relative to its proposed RCRA Subpart S soil action level. All COCs were at least one to two orders of magnitude below their corresponding action levels, except at Site 18 (which displayed PCBs above the proposed RCRA Subpart S soil action level). As indicated in the individual section for this site, the efficacy of conducting a VCM was evaluated. Three other sites (35, 36, and 196) also exhibited TPH above the New Mexico Underground Storage Tank Regulations (NMUSTR) standard, but each of these is proposed for NFA because TPH is in the form of a nonhazardous mineral oil.

23.0 ER SITE 241: STORAGE YARD

The Storage Yard is located in the southeastern portion of TA-III (Figure 23-1). The site includes a fenced area (180 ft x 230 ft) and areas to the west and south where scrap materials and equipment from TA-V were stored. Based on the types of materials stored at the site, potential COCs include metals, radioisotopes, HEs, and transformer oil. The field investigation and protocols are discussed below.

23.1 Field Investigation Protocols

Activities conducted at Site 241 in support of the RFI included aerial photograph analysis, surface radiation surveys, and surface soil sampling. Each is discussed in the following sections.

23.1.1 Aerial Photograph Analysis

Aerial photographs from 1973 to 1990 were assembled, digitized, and compared for changes in surface features during successive years at the Storage Yard. The area within 1,000 ft of the site boundaries was studied for signs of soil disturbance, vegetation changes, or new construction.

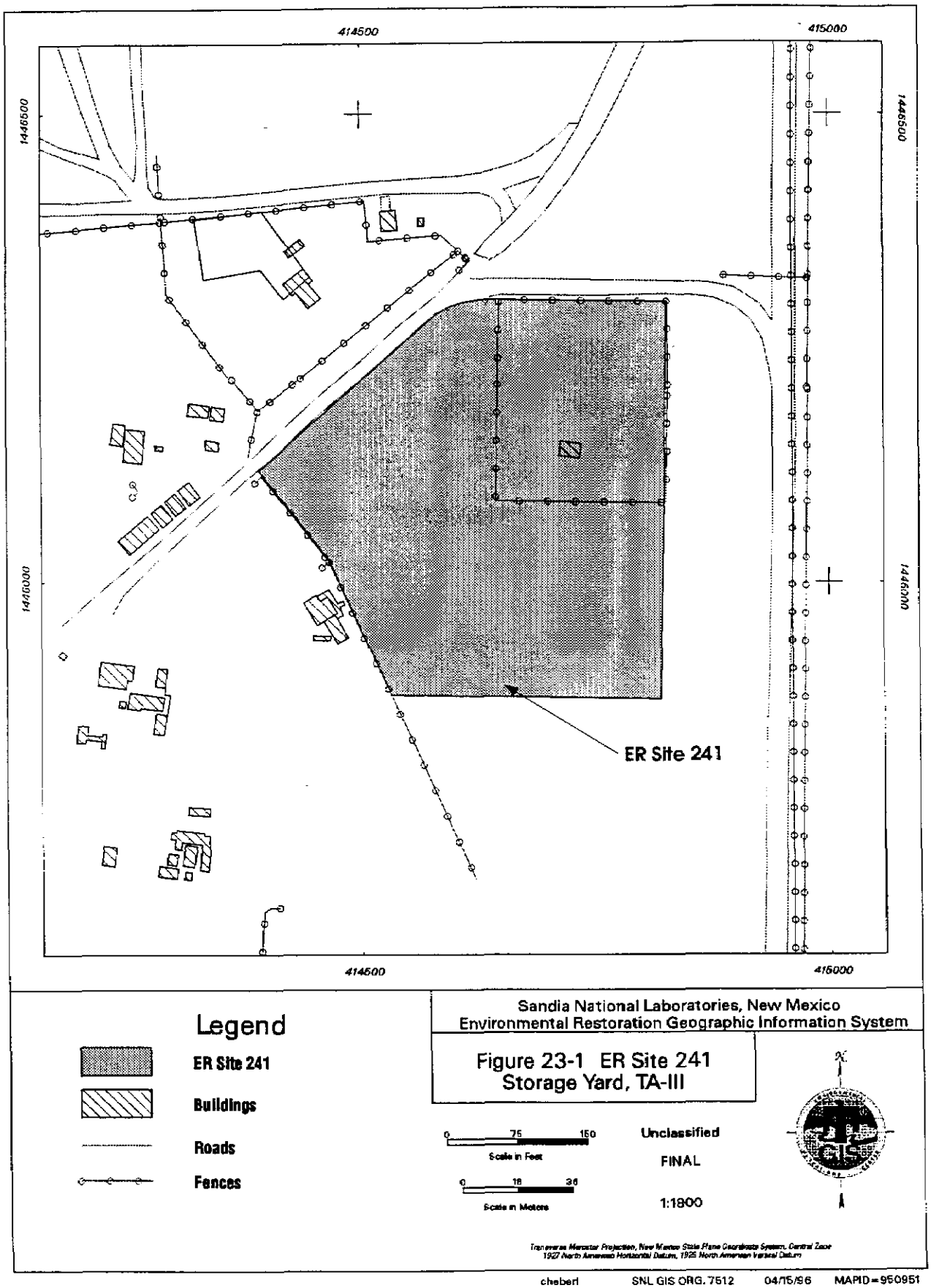
23.1.2 Equipment Removal Radiological Surveys

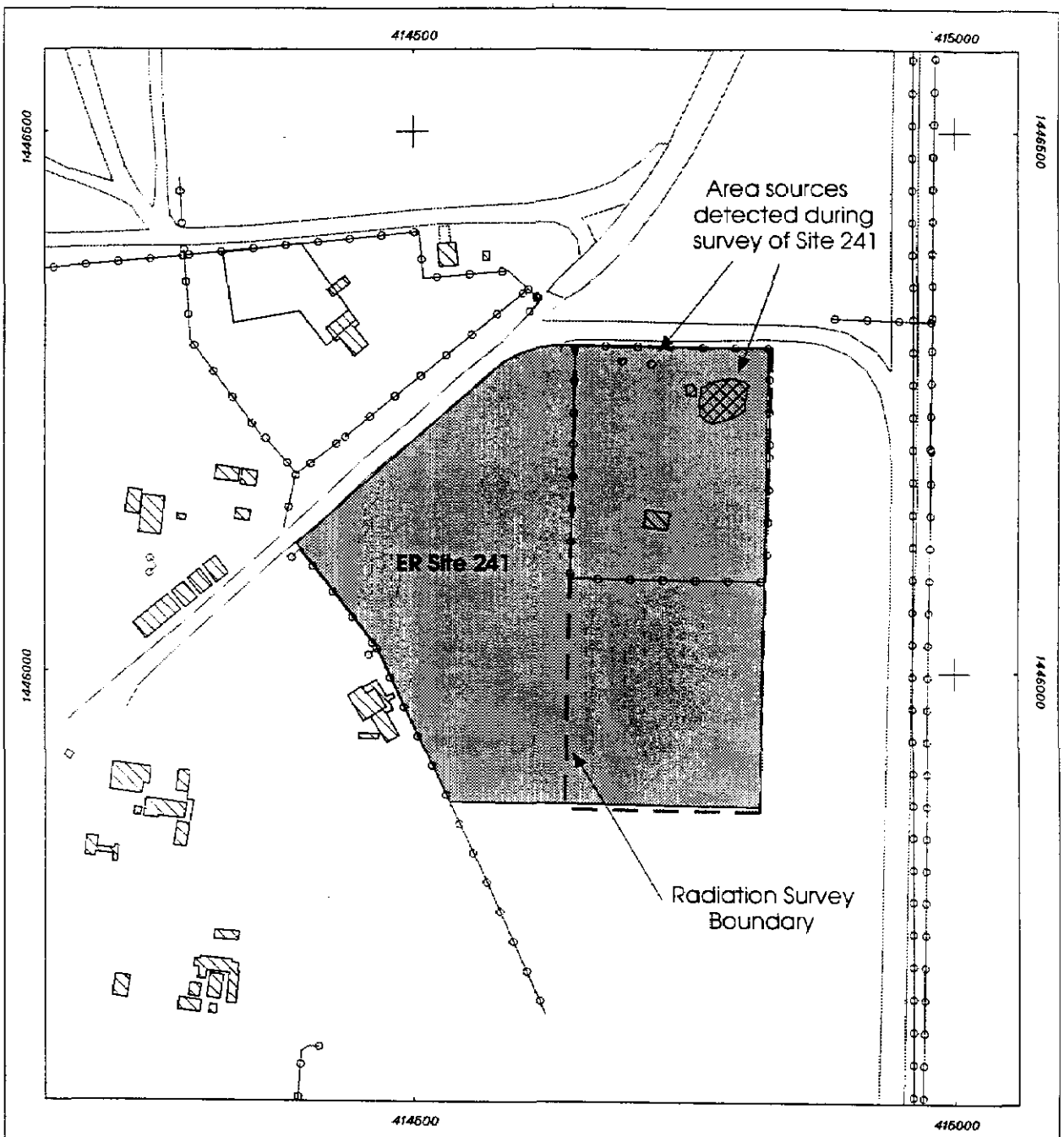
As part of the ER Project-wide surface radioactive materials survey conducted during April 1994, the Storage Yard was screened for radioactive materials. The radiological survey covered 1.8 acres of flat terrain with little or no vegetation (Figure 23-2). The northern half of the survey area is enclosed by a fence; the southern half is not enclosed. A gamma scan survey was performed on 6-ft centers over the exterior surface area of the site.

Site 241 was used to store materials and equipment removed from a reactor and associated laboratories in TA-V. Most of the stored materials were arranged in rows running east-west along the northern survey boundary; other equipment was distributed across the areas to the west and south of the fenced area. The TA-V equipment was removed, and a second radiological survey of the area was conducted; no residual radioactive material was found during the follow-up survey.

23.1.3 Surface Soil Sampling

In accordance with the RFI Work Plan (SNL/NM 1993a), soil samples were collected in May 1994 from a depth of 0 to 1 ft bgs from the locations shown in Figure 23-3; the locations were chosen using a random number generator, supplemented by additional samples near stored equipment. Sample coordinates are included in Appendix A. Field screening for metals was conducted using XRF techniques, and colorimetric kits were used to screen for HEs. Off-site laboratory analysis was performed for TPH, metals, HEs, and gamma spectroscopy in accordance with the EPA methods cited in


414500
415000
1446500
1446000
ER Site 241
Legend
ER Site 241
Buildings
Roads
Fences
Sandia National Laboratories, New Mexico
Environmental Restoration Geographic Information System
Figure 23-1 ER Site 241
Storage Yard, TA-III
0 75 150
Scale in Feet
0 18 36
Scale in Meters
Unclassified
FINAL
1:1800
Transverse Mercator Projection, New Mexico State Plane Coordinate System, Central Zone
1927 North American Horizontal Datum, 1929 North American Vertical Datum
cheberl SNL GIS ORG. 7512 04/15/96 MAPID=960951



Legend

- ER Site 241
- Buildings
- Surface Radiation Anomalies (Area Sources)
- Roads
- Fences
- Radiation Survey Boundary

Sandia National Laboratories, New Mexico
Environmental Restoration Geographic Information System

Figure 23-2 ER Site 241 Location of Surface Radiation Anomalies, TA-III

0 75 150
Scale in Feet

0 18 36
Scale in Meters

Unclassified

FINAL

1:1800

Transverse Mercator Projection, New Mexico State Plane Coordinate System, Central Zone
1927 North American Horizontal Datum, 1929 North American Vertical Datum

cheberl SNL GIS ORG. 7512 04/26/96 MAPID=950952

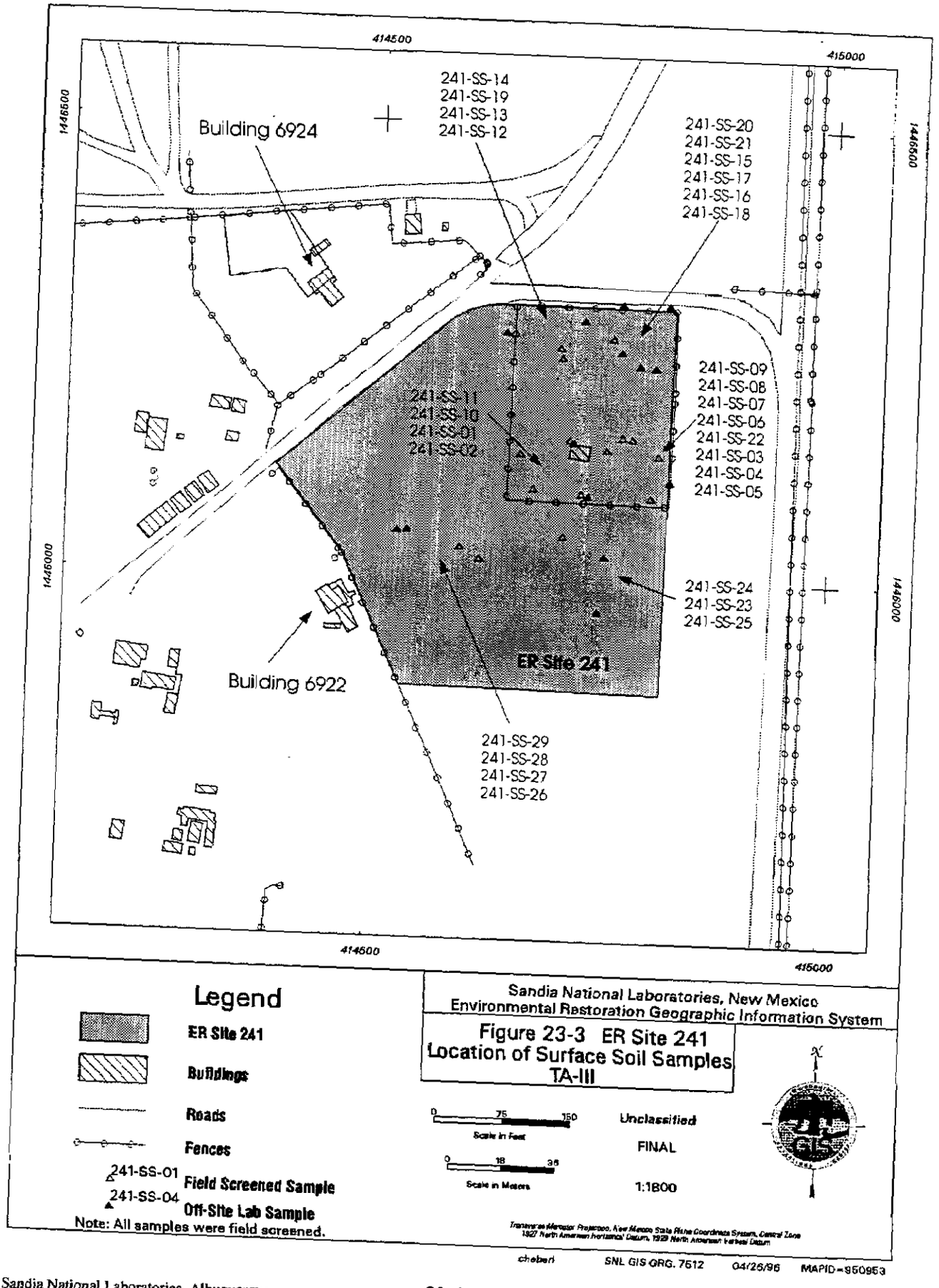

414500
415000
1446500
1446000
241-SS-14
241-SS-19
241-SS-13
241-SS-12
Building 6924
241-SS-20
241-SS-21
241-SS-15
241-SS-17
241-SS-16
241-SS-18
241-SS-09
241-SS-08
241-SS-07
241-SS-06
241-SS-22
241-SS-03
241-SS-04
241-SS-05
241-SS-11
241-SS-10
241-SS-01
241-SS-02
241-SS-24
241-SS-23
241-SS-25
ER Site 241
Building 6922
241-SS-29
241-SS-28
241-SS-27
241-SS-26
Legend
ER Site 241
Buildings
Roads
Fences
241-SS-01 Field Screened Sample
241-SS-04 Off-Site Lab Sample
Note: All samples were field screened.
Sandia National Laboratories, New Mexico
Environmental Restoration Geographic Information System
Figure 23-3 ER Site 241
Location of Surface Soil Samples
TA-III
0 75 150
Scale in Feet
0 18 36
Scale in Meters
Unclassified
FINAL
1:1800
cheberl
SNL GIS ORG. 7512
04/25/96
MAPID=950953

Table 2-2. Based on field observations, SNL/NM collected a separate sample from a piece of piping and analyzed it for asbestos; in addition, one sample was collected from the soil next to a transformer and analyzed for PCBs.

23.2 Field Investigation Results

23.2.1 Aerial Photograph Interpretation

The only feature found at this site was in 1986 (Plate I). A cleared or disturbed surface was found 600 ft west of Site 241 and extended 1,700 ft to the southwest. On-ground investigation confirmed this as a burned area.

23.2.2 Radiation Survey

The only anomalies detected during the first radiation survey of Site 241 were those associated with "shine" from the rows of activated equipment that had been stored on site (Figure 23-2; Table 23-1). They were not associated with soil contamination. No radiation anomalies were detected during the second site survey, conducted subsequent to the removal of equipment and materials.

Table 23-1
Areas of Gamma Activity Detected in First Radiation Survey of Site 241

Anomaly Type	Quantity	Gamma Radiation Activity (μR/hr)	Description
Soil Area Source	4	13 to >1,103[a]	Area sources appeared to be "shine" fields associated with possible activated materials stored within Site 241 boundaries. Not detected in second survey.

[a]The upper range of the instrument is 1,103 μR/hr.

23.2.3 Surface Soil Sampling

Table 23-2 summarizes all constituents that were detected in concentrations greater than the detection limit for the soil samples collected during the surface investigation. Detailed field screening results are provided in Appendix B. Soil sampling and QA/QC results are provided in electronic format in Appendices C and D.

Table 23-2
Summary of Detected Constituents of Concern in Site 241 Surface Soils

Analyte	Range (mg/kg)	Detection Limit (mg/kg)	Total Samples	Mean (mg/kg)	Number of Non-Detects	Samples ≤ Mean	Samples > Mean
Aluminum	3,300-5,690	10	15	4,612	0	8	7
Antimony	<6-29.6[a]	6	15	6.2	13	13	2
Aroclor-1248	0.060 (single)	0.033	1	NA[b]	NA	NA	NA
Arsenic	2.2-3.4	0.5	15	2.7	0	8	7
Barium	47.2-79.7	1	15	63	0	9	6
Beryllium	0.44-0.66	0.2	15	0.6	0	10	5
Cadmium	<0.5-1.6	0.5	15	0.7	6	12	3
Calcium	2,650-9,180	20	15	5,083	0	9	6
Chromium	5-7.5	1	15	6.4	0	8	7
Cobalt	2.3-3.8	1	15	2.8	0	10	5
Copper	5.4-34.4	2	15	8.2	0	11	4
Iron	6,140-12,300	10	15	7,632	0	8	7
Lead	6.8-685	0.5	15	18.8	0	12	3
Magnesium	1,300-2,090	20	15	1,673	0	8	7
Manganese	111-171	1	15	138	0	9	6
Mercury	<0.1-0.19	0.1	15	0.1	14	14	1
Nickel	<4-5.3	4	15	4	8	10	5
Potassium	1,100-1,920	500	15	1,542	0	8	7
Vanadium	10.1-16.8	1	15	12.8	0	7	8
Zinc	19.5-75.8	2	15	36	0	7	8

[a]Antimony results shown are from original, anomalous sampling. Resampling indicated no detectable antimony. Thus, all 15 samples were nondetects.
[b]NA = Not applicable.

No HEs were detected above their respective MDLs. No asbestos was detected in the sample submitted. PCBs (Aroclor-1248) were detected at a concentration of 60 µg/kg in the sample submitted (Table 23-2).

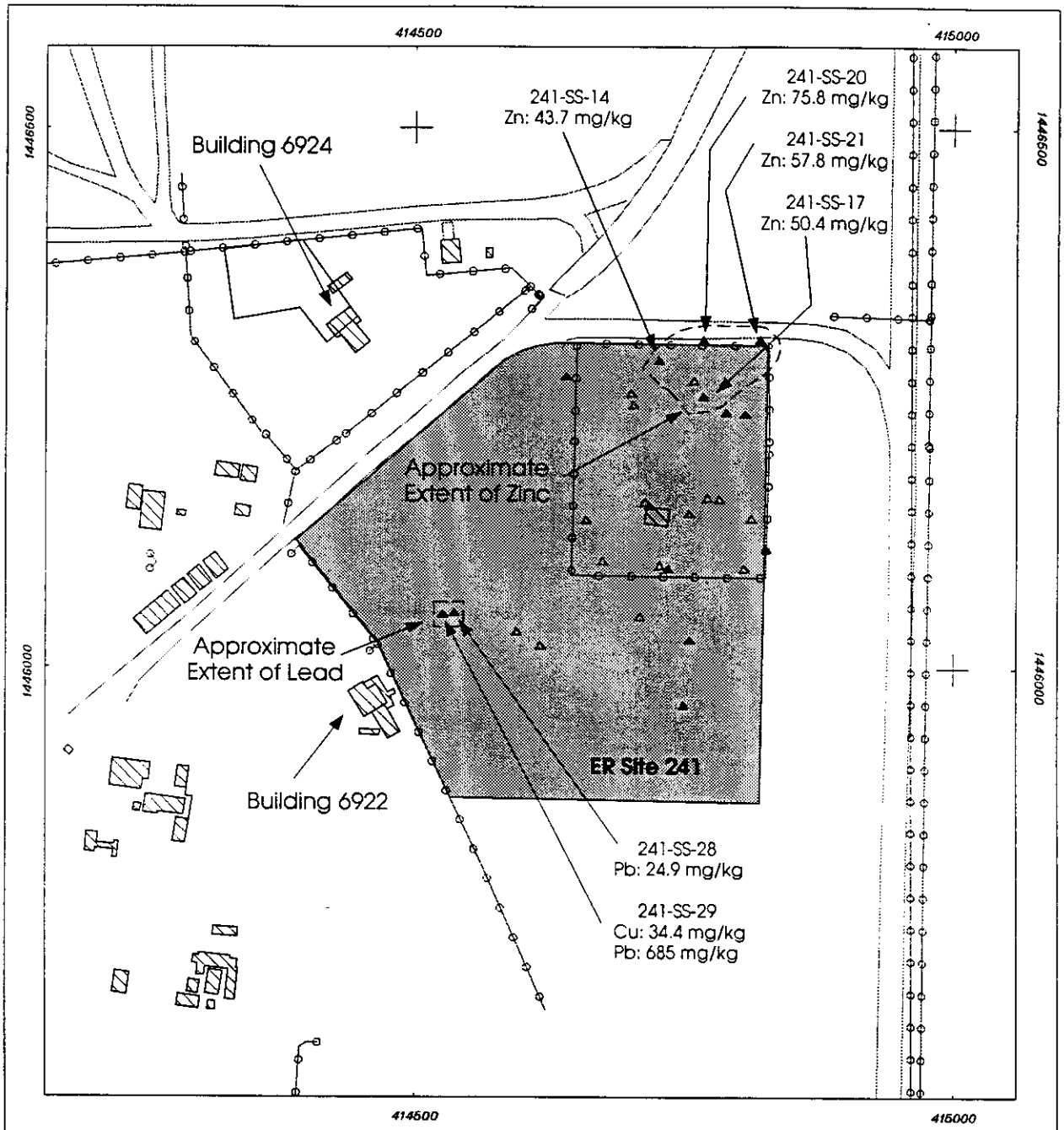
The gamma spectroscopy results were examined to determine whether any enriched or DU existed at the site. A uranium equilibrium analysis of the ratios of activities for U-234 to U-238 and the ratio of both radioisotopes to U-235 activity was completed. No uranium, or any other radionuclides covered by the broad gamma spectrum, were detected at an activity level to indicate contamination at the site; all were below their respective IT (1996) site-wide background UTLs (Appendix C).

Several metals were detected above their respective MDLs, but only copper, lead, and zinc were detected in excess of the calculated TA-III/V background UTLs (Table 23-3 and Figure 23-4). Only one sample contained copper above its UTL (14.5 mg/kg). Sample 241-SS-29 contained 34.4 mg/kg of copper; however, the duplicate of this sample, 241-SS-29D, contained only 6.6 mg/kg of copper. It is not, therefore, considered a site contaminant.

Table 23-3
Comparison of Site 241 Surface Soil Results to Technical Areas III and V Background Data

Parameter	Population Distribution	Statistical Test Applied				UTL[a] or 95th Percentile (mg/kg)	Maximum Concentration at Site 241 (mg/kg)	Site Contaminant[b]	Number of Samples that Exceed UTL
		Student's t-test		Wilcoxon	Quantile				
		Equal Variance	Unequal Variance						
Barium	Lognormal	Pass[c]	Fail[d]	Pass	Pass	341.0	79.7	No	0
Beryllium	Lognormal	Fail	Fail	Fail	Pass	0.7	0.66	No	0
Cadmium	Lognormal	Pass	Pass	Pass	Pass	2.6	1.6	No	0
Chromium	Lognormal	Pass	Pass	Pass	Pass	26.2	7.5	No	0
Copper	Lognormal	Fail	Fail	Fail	Pass	14.5	34.4	No	1[e]
Lead	Lognormal	Fail	Fail	Fail	Fail	24.8	685	Yes	3
Nickel	Lognormal	Pass	Pass	Pass	Pass	12.9	5.3	No	0
Zinc	Lognormal	Fail	Fail	Fail	Fail	41.8	75.8	Yes	4

[a]UTL.
[b]Assessment of site contaminant based upon a qualitative evaluation of each statistical test applied to the data. For example: If all tests "fail," the highest concentration is statistically "greater" than background. If one or more tests "pass," other criteria may indicate that the highest concentration is not obviously, or statistically, greater than background. Other criteria include (1) the power of the individual statistical test, and (2) whether the maximum concentration exceeds the UTL or 95th percentile.
[c]Pass = Accept the null hypothesis that test statistics are equal.
[d]Fail = Reject the null hypothesis that test statistics are equal.
[e]Only one sample (241-SS-29 with a concentration of 34.4 mg/kg of copper) exceeded its UTL; its duplicate (241-SS-29D with a concentration of 6.6 mg/kg of copper) did not.


414500
415000
1446600
1446000
241-SS-14
Zn: 43.7 mg/kg
241-SS-20
Zn: 75.8 mg/kg
241-SS-21
Zn: 57.8 mg/kg
241-SS-17
Zn: 50.4 mg/kg
Building 6924
Approximate
Extent of Zinc
Approximate
Extent of Lead
ER Site 241
Building 6922
241-SS-28
Pb: 24.9 mg/kg
241-SS-29
Cu: 34.4 mg/kg
Pb: 685 mg/kg
Legend
ER Site 241
Buildings
Roads
Fences
241-SS-01
Field Screened Sample
241-SS-04
Off-Site Lab Sample
Cu: 34.4 mg/kg
Concentration of Copper
Pb: 685 mg/kg
Concentration of Lead
Zn: 75.8 mg/kg
Concentration of Zinc
Note: Only those samples with concentrations of metals exceeding the UTLs are shown.
All samples were field screened.
Sandia National Laboratories, New Mexico
Environmental Restoration Geographic Information System
Figure 23-4 ER Site 241
Extent of Select Metals in Soil
TA-III
0 75 150
Scale in Feet
0 18 36
Scale in Meters
Unclassified
FINAL
1:1800
GIS
Transverse Mercator Projection, New Mexico State Plane Coordinate System, Central Zone
1927 North American Horizontal Datum, 1929 North American Vertical Datum
cheberl
SNL GIS ORG. 7512
04/26/96
MAPID=960172

Two samples contained anomalously elevated levels of antimony (11.2 and 29.6 mg/kg). Because the laboratory indicated problems with the matrix spike data for antimony, the locations were resampled and contained no detectable levels of antimony.

Because several metals are essential nutrients or are geologically prevalent (i.e., the soil-forming Sandia granite contains high concentrations of aluminum, calcium, iron, magnesium, manganese, and potassium), these metals were removed from further consideration. Furthermore, no proposed RCRA Subpart S soil action levels are currently promulgated for any of these constituents.

A statistical comparison of the arsenic, cobalt, mercury, and vanadium to TA-III/V background was not possible because there were no TA-III/V background data available for these constituents at the time the statistical analyses were completed. A comparison of these metals to the revised site-wide report (IT 1996) is shown in Table 23-4. None of these metals exceeded the site-wide UTLs.

Table 23-4
Comparison of Site 241 Data to Site-Wide Background

Parameter	Maximum Concentration (mg/kg)	Site-Wide UTL (IT 1996)
Arsenic	3.4	5.6
Cobalt	3.8	5.2
Mercury	0.19	0.31
Vanadium	16.8	20.4

Table 23-5 compares the maximum concentrations of the metals detected in concentrations above either TA-III/V or site-wide background to their respective proposed RCRA Subpart S soil action levels.

Table 23-5
Comparison of Site 241 Soil Analytical Results to Proposed RCRA Subpart S Soil Action Levels

Parameter	Maximum Concentration at Site 241 (mg/kg)	Proposed RCRA Subpart S Soil Action Level (mg/kg)	Exceeds Proposed RCRA Subpart S Soil Action Level?
Lead	685	2,000	No
PCBs	0.06	10	No
Zinc	75.8	20,000	No

23.3 Evaluation of Data

Neither of the two metals (lead and zinc) detected in excess of the TA-III/V UTLs exceeded its proposed RCRA Subpart S soil action level. The comparative action levels are those developed for residential land-use scenarios, rather than the industrial land-use assumed for TA-III/V; the action levels are therefore more conservative. Similarly, the concentration of PCBs in one sample did not exceed the proposed RCRA Subpart S soil action level.

23.4 Summary and Conclusions

Radiation surveys conducted at Site 241 indicated only "shine" from nearby activated equipment. No radioactive soil contamination was detected during the survey or in the subsequent confirmation gamma spectroscopic analyses.

Two metals (lead and zinc) were identified as site contaminants, but neither was above its proposed RCRA Subpart S soil action level. The site is therefore proposed for NFA.

24.0 SURFACE RADIOACTIVE MATERIAL SURVEY AND REMOVAL VOLUNTARY CORRECTIVE MEASURE

24.1 Introduction

A surface radioactive material survey and removal VCM was performed at 64 SNL/NM ER sites covering approximately 831 acres. The main purpose of the VCM was to remove known surficial (0 to 6 in. bgs) radioactive contamination, primarily DU, from uncontrolled hazardous waste sites. The survey and removal did not address deep contamination (greater than 6 in. bgs), which would be associated with penetration of DU as a result of highly energetic tests in some areas. The survey detected radioactive material to a maximum depth of 6 in.; the follow-on cleanup removed material to a maximum depth of 18 in. (i.e., if necessary, cleanup continued beyond a depth of 6 in. to a maximum of 18 in. bgs).

The VCM was one of the steps taken to ensure worker safety during any subsequent assessment, remediation, or facility activities, and was conducted to help restore the site to a condition that would allow unrestricted use of the formerly contaminated sites. DOE Grand Junction Projects Office (GJPO), through its prime contractor, Geotech, performed the work (Geotech 1994). The ER sites within TA-III/V that were surveyed included Sites 18, 83, 84, 102, 240, and 241. Those sites identified during the survey that exhibited radioactive soil anomalies (including point and fragment anomalies) will be retained in the SNL/NM RMMA program.

24.2 Trial Survey

A trial survey was conducted at Site 83 (Long Sled Track) to determine the effectiveness of instrument response to DU for the site-specific conditions at SNL/NM and to evaluate instrument detection limits qualitatively. Optimum scanning speed, grid spacing, and determination of natural background range also were established during the trial survey. All procedures and methods used in the trial and subsequent surveys complied with Nuclear Regulatory Commission (NRC) regulations and DOE guidelines (DOE 1983, 1992, 1994).

A "crutch" scintillometer was the instrument of choice during the trial survey for use during the Phase I surveys. The crutch scintillometer consisted of a conventional NaI detector mounted on a medical crutch to enable technicians to walk upright while surveying by sweeping the instruments in 6-ft-diameter arcs close (3 to 4 in.) to the ground. The instruments measured gross gamma activity in counts per second. The crutch scintillometer was effective in identifying small anomalies associated with DU contamination. The scintillometer readings (in counts per second) were converted to an exposure reading in microroentgens per hour (μR/hr) using a conversion factor derived specifically for DU from cross-correlation data collected with a pressurized ionization chamber (PIC) during the trial survey. The calculated minimum detectable activity (MDA) was 1.8 μR/hr above background for a 1-in.-diameter point source at a depth of 6 in. The scintillometers were able to detect DU fragments and oxides in soil at depths down to 6 in. The optimum survey speed was 0.5 mile per hour, and the only parameter that was changed from site to site was the instrument grid spacing.

24.3 Phase I Surface Radiation Surveys Within TA-III

Phase I surface radiation surveys throughout SNL/NM were conducted between October 1993 and May 1994; the six sites within TA-III were surveyed between February and April 1994 (Table 24-1). Variability in natural background radiation was determined to be a function of geologic rock type and, therefore, threshold values were determined at each individual ER Project site. Background levels were determined by taking several readings in the vicinity of the site, outside the area believed to be affected. Background levels at the TA-III sites ranged from 10 to 13 μR/hr. After background was determined, a reading that exceeded the upper background reading by 30 percent was designated an anomaly. All anomalies were marked in the field and identified on site maps; the locations of each were surveyed at a later time.

Table 24-1
Technical Area III Surface Radiation Surveys

ER Site Number	Site Name	Grid Size/ Actual Acreage Covered	Number of Anomalies		Site-Specific Background Range (μR/hr)	Highest Value (μR/hr)
			Point Source	Area Source		
18	Concrete Pad	6-ft centers; 1.9 acres	1	0	10 to 12	17
83	Long Sled Track	10-ft centers; 176.3 acres	1,361	33	10 to 13	>1,103[a]
84	Gun Facilities	6-ft centers; 7.4 acres	50	9	10 to 12	>1,103
102	Radioactive Disposal	10-ft centers; 4.4 acres	0	0	10 to 13	0
240	Short Sled Track	10-ft centers; 82.6 acres	251	9	10 to 12	308
241	Storage Yard	6-ft centers; 1.8 acres	0	4	11 to 12	>1,103
		TOTAL	1,663	55		

[a]The amount 1,103 μR/hr represents the maximum value that the scintillometers were capable of detecting (converted from counts per second).

A total of 1,718 anomalies were detected during the surface radiation surveys at the TA-III sites (Table 24-1). Among the anomalies detected, 1,663 were determined to be point sources and 55 were considered area sources. Point sources were discrete and typically associated with metallic fragments or a small area within the soil. Area sources included associations of metallic fragments or more dispersed soil contamination, gamma radiation fields associated with radioactive materials storage areas, and gamma radiation associated with natural geologic outcrops.

The majority of the point source anomalies ranged from approximately 15 to 100 μR/hr. Elevated area source values ranged from 11 to 1,103 μR/hr, which is the upper range of the scintillometer (converted from counts per second).

In some cases, anomalies with readings higher than the localized upper range of background were related to unique geologic features exhibiting naturally occurring elevated gamma readings. If the area of the unique geological feature was extensive, the range was adjusted and the area was not mapped as an anomaly. In cases where the geological features were more localized, the areas were mapped as "outcrop" anomalies for follow-up verification and were suspected of being anthropogenic anomalies. If any uncertainty existed about the correlation of elevated readings to geologic features, the areas were mapped as anomalies.

24.4 Results of the Surface Radiation Surveys

Visible uranium contamination occurred in the field as very hard metallic fragments of DU test components or as oxidized coatings on silt or sand-size soil particles. DU in metal alloy form or as the oxidized coatings was not found to be migrating significantly into the subsurface from near surface locations where it was detected.

Discussions of the surveyed areas and the survey results for each of the TA-III sites are provided in the individual site sections (Sites 18, 83, 84, 102, 240, and 241). Further details can be found in the final report issued on the radiation survey (Geotech 1994).

24.5 Radioactive Material Removal

Upon completion of the radiation survey, the radiation anomalies detected at the sites in TA-III were removed. Reasonable attempts were made to clean up the soil to site-specific background levels. Discussions of site-specific removal activities are included in the individual site sections.

Gamma scintillometers and GM pancake probes (beta-gamma detectors) were used together to verify anomaly locations and to screen both the soil and fragments for residual elevated radioactivity (above background). Field instrument alarms were set to the minimum detectable count rate above background (i.e., approximately 1.3 times the site-specific background) per DOE and NRC guidance. Sampling and analysis were conducted at selected anomalies at each site (approximately 10 percent by site) to determine the effectiveness of the removal action. Laboratory gamma-spectroscopy soil analyses were performed to quantitatively determine the remaining activity in the soil; the results of the confirmation analyses are provided in Appendix G.

24.5.1 Radioactive Material Removal Procedures

To prepare the sites for radioactive materials removal, all survey areas were flagged and identified on a base map for each site. The points were land surveyed for future retrieval. Upon returning to the field to remove the anomalies, it was discovered that not all were easily located. In these cases, the anomaly coordinates were entered into a Global Positioning System (GPS) and relocated using the GPS navigational system. The locations were verified with a NaI scintillometer.

The following removal procedures were used:

- Selected anomaly;
- Scanned anomaly with NaI detector;
- Removed anomaly and placed in a 55-gal. open-head steel drum;
- Screened the immediate area using a GM pancake probe and a NaI detector, and compared instrument reading to site-specific background levels;
- If measurements exceeded background levels, attempted to locate the source of the radioactivity by removing soil in small amounts up to 18 in. bgs and spreading the soil on a plastic sheet next to the anomaly to scan and segregate the contaminated soil;
- When readings were less than 1.3 times background levels, removal action was considered complete;
- Recorded final soil measurement and highest reading prior to removal; and
- Collected soil samples from cleaned areas to verify cleanup at a rate of 10 percent of the anomaly locations by site for analysis using standard laboratory gamma-spectroscopy methods.

24.6 Migration and Transport of Depleted Uranium

Both the metallic and oxidized forms of DU are insoluble in rain and surface water, although direct exposure to fast-running water could have resulted in physical transport of the oxide material. Thus, the processes most likely to affect the Phase I data within the ER Project characterization and cleanup timeframe would be physical processes, such as those related to construction, earth-moving, and grading activities. Erosion by wind and water should not significantly impact transport because the high density of DU metal and the density of the uranium oxide, produced by uranium corrosion, typically are higher than most of the naturally occurring fine-grained materials that make up the soil.

24.7 Summary and Conclusions

The surface radioactive material survey and removal VCM at six ER sites within TA-III identified 1,718 radiation anomalies in soil. The majority of the anomalies were related to metal fragments coated with DU and to soil containing oxidized uranium. All but four area sources were completely removed, and verification sampling and analysis indicated little to no residual radioactive material. The majority of the remaining radiation anomalies will be removed in spring 1996.

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APPENDIX E
EXAMPLE STATISTICAL CALCULATIONS

Appendix E
Example Calculations

Introduction

This appendix presents the statistical approach used to analyze and quantify data collected for ER site characterization activities at SNL/NM. Distribution analyses were determined for two background sample data sets collected at SNL/NM. For comparison purposes, normal and lognormally-transformed data were used in the distribution analyses. Data sets from two hypothetical ER Sites were compared to SNL/NM background data to demonstrate the statistical approach used to evaluate ER site data.

To determine the range of background concentrations, the 95th upper tolerance limit (UTL) or the 95th percentile were calculated for parametric and non-parametric data sets, respectively. The following steps were completed to arrive at a 95th UTL or percentile value: 1) *a priori* screening of the data; 2) determination of the percentage of non-detects in the data sets; 3) distribution analysis of the portion of the data set that exhibited less than 15% non-detects, including calculation of the coefficient of skewness and Shapiro-Wilk Test of Normality and interpretation of histograms and probability plots; 4) a second screening of the data performed by the calculation of the T_n statistic for parametric data; and finally 5) calculation of the 95th UTL for parametric data sets or the 95th percentile for non-parametric data sets.

After the 95th UTL or 95th percentile was calculated, background data sets were compared to the ER site-specific data sets. This comparison added credence to the UTL by determining if the background and site-specific data were statistically similar. For parametric background data sets, comparison analyses were conducted using the F distribution, the Student's t-test, the Wilcoxon Rank-Sum Test, and the Quantile test. Comparison analyses of non-parametric background data sets were analyzed by the Wilcoxon Rank-Sum Test and the Quantile test.

In some instances, comparison tests were performed to determine whether background samples collected from different depth intervals were similar and therefore could be combined. Probability plots and the Wilcoxon Rank-Sum test were used for comparison analysis.

1. Distribution Analyses

A distribution analysis was performed to determine if a particular data set was parametric or non-parametric. The data first were subjected to an *a priori* screen (Section 1.2). The number of non-detects were then evaluated for the data set (Section 1.3). If greater than 15% non-detects existed, the data set was considered non-parametric and the distribution analysis was concluded. If fewer than 15% non-detects existed, the data were subjected to two numerical and two graphical procedures to help determine the distribution type. The numerical procedures used were the coefficient of skewness (Section 1.4) and the Shapiro-Wilk Test of Normality (Section 1.5). The graphical procedures used were the histogram (Section 1.6) and the probability plot (Section 1.7). The results of the four procedures were compared and the distribution was determined (Section 1.8). The T_n statistic was then calculated for the parametric data sets as a second screening mechanism for outliers (Section 1.9). If a data set contained fewer than 15% non-detects but failed the numerical and graphical procedures for a parametric distribution, the data set was often carried through to the T_n statistic procedure to determine if outliers were present. In some instances, outliers were identified and removed during the T_n statistic procedure. This allowed the data set that had initially failed to pass the parametric numerical and graphical tests. If outliers were identified during the T_n statistical test, the outliers were removed and the mean and standard deviation were recalculated for the data set.

1.1 Background Data Sets

Tables E-1 and E-2 present SNL/NM background data sets for antimony and copper, respectively. The tables provide the raw analytical data, coded values, natural log-transformed data from each sample location, and instrument detection limits. A coded value is identical to the raw data value except when a concentration was reported below the instrument detection limit. The coded value in this case is one half of the instrument detection limit. The coded data set was used for the background antimony distribution analysis because of the presence of a non-detect.

Table E-1. Antimony Data for SNL/NM Background (in mg/kg)

Sample ID	Raw Data	Coded Value	Natural Log of Coded Value	Instrument Detection Limit
T1BS1-BH005-002-SS	0.439	0.439	-0.823	0.0887
T1BS1-BH016-002-SS	0.396	0.396	-0.926	0.0939
T1BS1-BH012-002-SS	0.326	0.326	-1.121	0.0929
T1BS1-BH008-002-SS	0.317	0.317	-1.149	0.0887
T1BS1-BH015-002-SS	0.277	0.277	-1.284	0.0929
T1BS1-BH010-002-SS	0.243	0.243	-1.415	0.0929
T1BS1-BH009-002-SS	0.217	0.217	-1.528	0.0922
T1BS1-BH002-002-SS	0.197	0.197	-1.625	0.0958
T1BS1-BH014-002-SS	0.191	0.191	-1.655	0.0929
T1BS1-BH003-002-SS	0.186	0.186	-1.682	0.0912
T1BS1-BH011-002-SS	0.184	0.184	-1.693	0.0922
T1BS1-BH004-002-SS	0.159	0.159	-1.839	0.0912
T1BS1-BH013-002-SS	0.119	0.119	-2.129	0.0904
T1BS1-BH006-002-SS	0.11	0.11	-2.21	0.0948
T1BS1-BH007-002-SS	0.104	0.104	-2.263	0.0922
T1BS1-BH001-002-SS	U	0.0479	-3.039	0.0958

Basic statistical parameters for the antimony data are:

Raw	Coded	Lognormal (Coded)
Mean (N=15) = 0.23	Mean (N=16) = 0.22	Mean (N=16) = -1.65
Standard Deviation = 0.10	Standard Deviation = 0.11	Standard Deviation = 0.57
Variance = 0.01	Variance = 0.01	Variance = 0.32

U = Concentration was below instrument detection limit

Table E-2. Copper Data for SNL/NM Background (in mg/kg)

Sample ID	Raw Data	Natural Log of Raw Data	Instrument Detection Limit
T1BS1-BH005-002-SS	20.1	3.00	0.0499
T1BS1-BH006-002-SS	10.8	2.38	0.0534
T1BS1-BH008-002-SS	9.71	2.27	0.0499
T1BS1-BH012-002-SS	9.52	2.25	0.0523
T1BS1-BH011-002-SS	9.16	2.21	0.0519
T1BS1-BH003-002-SS	9.13	2.21	0.0513
T1BS1-BH010-002-SS	8.29	2.12	0.0523
T1BS1-BH016-002-SS	7.78	2.05	0.0528
T1BS1-BH001-002-SS	7.72	2.04	0.0539
T1BS1-BH004-002-SS	7.58	2.03	0.0513
T1BS1-BH007-002-SS	7.58	2.03	0.0519
T1BS1-BH002-002-SS	7.35	1.99	0.0539
T1BS1-BH014-002-SS	6.34	1.85	0.0523
T1BS1-BH009-002-SS	5.17	1.64	0.0519
T1BS1-BH015-002-SS	4.87	1.58	0.0523
T1BS1-BH013-002-SS	3.85	1.35	0.0509

Basic statistical parameters for the copper data are:

Normal	Lognormal
Mean (N=16) = 8.43	Mean = 2.06
Standard Deviation = 3.63	Standard Deviation = 0.37
Variance = 13.19	Variance = 0.14

1.2 Rejection of Outliers: *A Priori* Test

The *a priori* test is a screening test used to eliminate outliers before the distribution analysis is performed (EPA 1992a). For the *a priori* test outliers are defined as maximum values greater than three times the next highest value (EPA 1992a). Non-transformed coded data are used for this screening test. If a data value fails the *a priori* test, it is removed from the data set for all following statistical analyses. The data point, however, must be explained as either potential sampling error, laboratory error, an anomalously high value, or some other factor contributing to an unexpectedly large concentration.

Antimony, *a priori*:

Sample ID	Raw Data	Coded Value	Instrument Detection Limit	Rank	Multiplicative Factor*	Outlier ?
T1BS1-BH005-002-SS	0.439	0.439	0.0887	1	1.1	No
T1BS1-BH016-002-SS	0.396	0.396	0.0939	2	1.2	No
T1BS1-BH012-002-SS	0.326	0.326	0.0929	3	1.0	No
T1BS1-BH008-002-SS	0.317	0.317	0.0887	4	1.1	No
T1BS1-BH015-002-SS	0.277	0.277	0.0929	5	1.1	No
T1BS1-BH010-002-SS	0.243	0.243	0.0929	6	1.1	No
T1BS1-BH009-002-SS	0.217	0.217	0.0922	7	1.1	No
T1BS1-BH002-002-SS	0.197	0.197	0.0958	8	1.0	No
T1BS1-BH014-002-SS	0.191	0.191	0.0929	9	1.0	No
T1BS1-BH003-002-SS	0.186	0.186	0.0912	10	1.0	No
T1BS1-BH011-002-SS	0.184	0.184	0.0922	11	1.2	No
T1BS1-BH004-002-SS	0.159	0.159	0.0912	12	1.3	No
T1BS1-BH013-002-SS	0.119	0.119	0.0904	13	1.1	No
T1BS1-BH006-002-SS	0.11	0.11	0.0948	14	1.1	No
T1BS1-BH007-002-SS	0.104	0.104	0.0922	15	2.2	No
T1BS1-BH001-002-SS	U	0.0479	0.0958	16	NA	No

* - multiplicative factor is determined by dividing a value by the next highest ranked value.
NA - Not Applicable

Interpretation: No outliers were eliminated from the antimony data set via the *a priori* screening method.

Copper, *a priori*:

Sample ID	Raw Data	Instrument Detection Limit	Rank	Multiplicative Factor*	Outlier?
TIBSI-BH005-002-SS	20.1	0.0499	1	1.9	No
TIBSI-BH006-002-SS	10.8	0.0534	2	1.1	No
TIBSI-BH008-002-SS	9.71	0.0499	3	1.0	No
TIBSI-BH012-002-SS	9.52	0.0523	4	1.0	No
TIBSI-BH011-002-SS	9.16	0.0519	5	1.0	No
TIBSI-BH003-002-SS	9.13	0.0513	6	1.1	No
TIBSI-BH010-002-SS	8.29	0.0523	7	1.1	No
TIBSI-BH016-002-SS	7.78	0.0528	8	1.0	No
TIBSI-BH001-002-SS	7.72	0.0539	9	1.0	No
TIBSI-BH004-002-SS	7.58	0.0513	10	1.0	No
TIBSI-BH007-002-SS	7.58	0.0519	11	1.0	No
TIBSI-BH002-002-SS	7.35	0.0539	12	1.2	No
TIBSI-BH014-002-SS	6.34	0.0523	13	1.2	No
TIBSI-BH009-002-SS	5.17	0.0519	14	1.1	No
TIBSI-BH015-002-SS	4.87	0.0523	15	1.3	No
TIBSI-BH013-002-SS	3.85	0.0509	16	NA	No

NA - Not Applicable

Interpretation: No outliers were eliminated from the copper data set via the *a priori* screening method.

1.3 Determination of Percent Non-detects

If the percentage of non-detects was less than 15%, a parametric distribution analysis was performed. If the percentage of non-detects was greater than 15%, the distribution was considered non-parametric and a distribution analysis was not performed (EPA 1992a,b).

The SNL/NM background antimony data set had one non-detect out of 16 samples, or 6% non-detects. The SNL/NM background copper data set had zero non-detects. Both data sets were eligible for the parametric distribution analysis.

1.4 Coefficient of Skewness

The coefficient of skewness indicates to what degree a data set is skewed or asymmetric with respect to the mean. Data from a perfectly shaped normal distribution have a coefficient of skewness of zero, while asymmetric data have either positive or negative skewness depending on whether the right- or left-hand tail of the distribution is longer and "skinnier" than the opposite tail. A small degree of skewness (between -1 and +1) is not likely to affect the results of statistical tests based on an assumption of normality. However, if the coefficient of skewness is larger than 1 (in absolute value) and the sample size is small (e.g., n<25), statistical research has shown that standard normal theory-based tests are much less powerful than when the absolute skewness is less than 1 (Gayen, 1949). Therefore, it is considered a failure of the test for normality if the coefficient of skewness exceeds 1. The formula for the coefficient of skewness γ_i is shown below, where n is the number of data points, x_i is an individual sample observation, $\bar{x}$ is the mean of the data set, and σ is the standard deviation.

$$\gamma_i = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^3}{\left(\frac{n-1}{n}\right)^{\frac{3}{2}}(\sigma)^3}$$

The Coefficient of Skewness can also be used to evaluate whether the distribution of a data set is more normal or lognormal, based on the closeness of γ_i to zero.

Coefficient of Skewness Calculations for Background Antimony at SNL/NM: Normal

Sample ID	Coded Value	Mean	$(x_i - \bar{x})$	$(x_i - \bar{x})^3$
T1BS1-BH005-002-SS	0.439	0.220	0.219	0.011
T1BS1-BH016-002-SS	0.396	0.220	0.176	0.005
T1BS1-BH012-002-SS	0.326	0.220	0.106	0.001
T1BS1-BH008-002-SS	0.317	0.220	0.097	0.001
T1BS1-BH015-002-SS	0.277	0.220	0.057	0.000
T1BS1-BH010-002-SS	0.243	0.220	0.023	0.000
T1BS1-BH009-002-SS	0.217	0.220	-0.003	0.000
T1BS1-BH002-002-SS	0.197	0.220	-0.023	0.000
T1BS1-BH014-002-SS	0.191	0.220	-0.029	0.000
T1BS1-BH003-002-SS	0.186	0.220	-0.034	0.000
T1BS1-BH011-002-SS	0.184	0.220	-0.036	0.000
T1BS1-BH004-002-SS	0.159	0.220	-0.061	0.000
T1BS1-BH013-002-SS	0.119	0.220	-0.101	-0.001
T1BS1-BH006-002-SS	0.11	0.220	-0.110	-0.001
T1BS1-BH007-002-SS	0.104	0.220	-0.116	-0.002
T1BS1-BH001-002-SS	0.0479	0.220	-0.172	-0.005
				Sum = 0.009

thus, for a normal distribution,

$$\gamma_i = \frac{\frac{0.009}{16}}{(0.908)(0.001)}$$

$$\gamma_i = 0.62$$

Coefficient of Skewness Calculations for Background Antimony at SNL/NM: Lognormal

Sample ID	Log (Coded Value)	Mean	$(x_i - \bar{x})$	$(x_i - \bar{x})^3$
T1BS1-BH005-002-SS	-0.823	-1.65	0.827	0.566
T1BS1-BH016-002-SS	-0.926	-1.65	0.724	0.380
T1BS1-BH012-002-SS	-1.121	-1.65	0.529	0.148
T1BS1-BH008-002-SS	-1.149	-1.65	0.501	0.126
T1BS1-BH015-002-SS	-1.284	-1.65	0.366	0.049
T1BS1-BH010-002-SS	-1.415	-1.65	0.235	0.013
T1BS1-BH009-002-SS	-1.528	-1.65	0.122	0.002
T1BS1-BH002-002-SS	-1.625	-1.65	0.025	0.00
T1BS1-BH014-002-SS	-1.655	-1.65	-0.005	0.00
T1BS1-BH003-002-SS	-1.682	-1.65	-0.032	0.00
T1BS1-BH011-002-SS	-1.693	-1.65	-0.044	0.00
T1BS1-BH004-002-SS	-1.839	-1.65	-0.189	-0.007
T1BS1-BH013-002-SS	-2.129	-1.65	-0.479	-0.110
T1BS1-BH006-002-SS	-2.21	-1.65	-0.560	-0.176
T1BS1-BH007-002-SS	-2.263	-1.65	-0.613	-0.230
T1BS1-BH001-002-SS	-3.039	-1.65	-1.389	-2.680
				Sum = -1.919

For a lognormal distribution,

$$\gamma_i = \frac{\frac{-1.919}{16}}{(0.908)(0.183)}$$

$$\gamma_i = -0.72$$

Interpretation: The data set more closely represents a normal distribution, because the coefficient of skewness for the normal distribution is closer to zero.

Coefficient of Skewness Calculations for Background Copper at SNL/NM: Normal

Sample ID	Raw Data	Mean	$(x_i - \bar{x})$	$(x_i - \bar{x})^3$
T1BS1-BH005-002-SS	20.1	8.43	11.67	1589.32
T1BS1-BH006-002-SS	10.8	8.43	2.37	13.31
T1BS1-BH008-002-SS	9.71	8.43	1.28	2.10
T1BS1-BH012-002-SS	9.52	8.43	1.09	1.30
T1BS1-BH011-002-SS	9.16	8.43	0.73	0.39
T1BS1-BH003-002-SS	9.13	8.43	0.70	0.34
T1BS1-BH010-002-SS	8.29	8.43	-0.14	0.00
T1BS1-BH016-002-SS	7.78	8.43	-0.65	-0.27
T1BS1-BH001-002-SS	7.72	8.43	-0.71	-0.36
T1BS1-BH004-002-SS	7.58	8.43	-0.85	-0.61
T1BS1-BH007-002-SS	7.58	8.43	-0.85	-0.61
T1BS1-BH002-002-SS	7.35	8.43	-1.08	-1.26
T1BS1-BH014-002-SS	6.34	8.43	-2.09	-9.13
T1BS1-BH009-002-SS	5.17	8.43	-3.26	-34.65
T1BS1-BH015-002-SS	4.87	8.43	-3.56	-45.12
T1BS1-BH013-002-SS	3.85	8.43	-4.58	-96.07
				Sum = 1418.67

thus, for a normal distribution,

$$\gamma_i = \frac{\frac{1418.67}{16}}{(0.91)(47.83)}$$

$$\gamma_i = \frac{88.67}{43.53}$$

$$\gamma_i = 2.04$$

Coefficient of Skewness Calculations for Background Copper at SNL/NM: Lognormal

Sample ID	Log (Coded Value)	Mean	$(x_i - \bar{x})$	$(x_i - \bar{x})^3$
T1BS1-BH005-002-SS	3.00	2.06	0.94	0.83
T1BS1-BH006-002-SS	2.38	2.06	0.32	0.03
T1BS1-BH008-002-SS	2.27	2.06	0.21	0.01
T1BS1-BH012-002-SS	2.25	2.06	0.19	0.01
T1BS1-BH011-002-SS	2.21	2.06	0.15	0.00
T1BS1-BH003-002-SS	2.21	2.06	0.15	0.00
T1BS1-BH010-002-SS	2.12	2.06	0.06	0.00
T1BS1-BH016-002-SS	2.05	2.06	-0.01	0.00
T1BS1-BH001-002-SS	2.04	2.06	-0.02	0.00
T1BS1-BH004-002-SS	2.03	2.06	-0.03	0.00
T1BS1-BH007-002-SS	2.03	2.06	-0.03	0.00
T1BS1-BH002-002-SS	1.99	2.06	-0.07	0.00
T1BS1-BH014-002-SS	1.85	2.06	-0.21	-0.01
T1BS1-BH009-002-SS	1.64	2.06	-0.42	-0.07
T1BS1-BH015-002-SS	1.58	2.06	-0.48	-0.11
T1BS1-BH013-002-SS	1.35	2.06	-0.71	-0.36
				Sum = 0.33

For a lognormal distribution,

$$\gamma_i = \frac{\frac{0.33}{16}}{(0.91)(0.052)}$$

$$\gamma_i = \frac{.021}{0.047}$$

$$\gamma_i = 0.45$$

Interpretation: The data set more closely represents a lognormal distribution, because the coefficient of skewness for the lognormal distribution is between -1 and 1.

1.5 Shapiro-Wilk Test of Normality

The Shapiro-Wilk Test of Normality is based on the premise that, if a set of data is normally distributed, the ordered values should be highly correlative with corresponding quantiles taken from a normal distribution (Shapiro and Wilk, 1965). In particular, the Shapiro-Wilk Test of Normality gives substantial weight to evidence of non-normality in the tails of a distribution, where the robustness of statistical tests based on the normality assumption is the most severely affected (EPA, 1992a).

The Shapiro-Wilk test statistic (W) will tend to be large (close to 1) when the data is normally distributed. Only when the plotted data show significant bends or curves will the test statistic be small.

The Shapiro-Wilk Test of Normality is considered to be one of the best available tests of normality (Miller, 1986; Madansky, 1988).

The following formula is used to calculate W:

$$W = \left[\frac{b}{\sigma \sqrt{n-1}} \right]^2$$

where,

$$b = \sum_{i=1}^{k} b_i = \sum_{i=1}^{k} a_{n-i+1} \left(x_{(n-i+1)} - x_i \right)$$

and σ = standard deviation,
n = number of data points,
a_{n-i+1} = coefficients determined from Table A-1in EPA (1992a) for $3 \leq n \leq 50$
K = greatest integer less than or equal to n/2

Normality of the data should be rejected if the Shapiro-Wilk statistic is too low when compared to the critical values provided in Table A-2 (EPA, 1992a). Otherwise, the data are assumed to be approximately normal for purposes of further statistical analysis.

Shapiro-Wilk Test of Normality for Background Antimony at SNL/NM: Normal

Sample ID	x_i	$x_{(n-i+1)}$	$x_{(n-i+1)}-x_i$	a_{n-i+1}	b_i
T1BS1-BH001-002-SS	0.0479	0.439	0.3911	0.5056	0.1977401
T1BS1-BH007-002-SS	0.104	0.396	0.292	0.329	0.096068
T1BS1-BH006-002-SS	0.11	0.326	0.216	0.2521	0.0544536
T1BS1-BH013-002-SS	0.119	0.317	0.198	0.1939	0.0383922
T1BS1-BH004-002-SS	0.159	0.277	0.118	0.1447	0.0170746
T1BS1-BH011-002-SS	0.184	0.243	0.059	0.1005	0.0059295
T1BS1-BH003-002-SS	0.186	0.217	0.031	0.0593	0.0018383
T1BS1-BH014-002-SS	0.191	0.197	0.006	0.0196	0.0001176
T1BS1-BH002-002-SS	0.197	0.191	-0.006		
T1BS1-BH009-002-SS	0.217	0.186	-0.031		
T1BS1-BH010-002-SS	0.243	0.184	-0.059		
T1BS1-BH015-002-SS	0.277	0.159	-0.118		
T1BS1-BH008-002-SS	0.317	0.119	-0.198		
T1BS1-BH012-002-SS	0.326	0.11	-0.216		
T1BS1-BH016-002-SS	0.396	0.104	-0.292		
T1BS1-BH005-002-SS	0.439	0.0479	-0.3911		

sum of b_i ($\sum b_i$) = 0.41161396
standard deviation (σ) = 0.10840795
count - 1 (n-1) = 15
W statistic = 0.961
critical value (n = 16) = 0.887
Shapiro-Wilk Test for Normality = Pass

Shapiro-Wilk Test of Normality for Background Antimony at SNL/NM: Log Data

Sample ID	x_i	$x_{(n-i+1)}$	$x_{(n-i+1)}-x_i$	a_{n-i+1}	b_i
T1BS1-BH001-002-SS	-3.03864	-0.82326	2.215383909	0.5056	1.120098
T1BS1-BH007-002-SS	-2.26336	-0.92634	1.337023312	0.329	0.439881
T1BS1-BH006-002-SS	-2.20727	-1.12086	1.086417016	0.2521	0.273886
T1BS1-BH013-002-SS	-2.12863	-1.14885	0.979778281	0.1939	0.189979
T1BS1-BH004-002-SS	-1.83885	-1.28374	0.555113304	0.1447	0.080325
T1BS1-BH011-002-SS	-1.69282	-1.41469	0.278125686	0.1005	0.027952
T1BS1-BH003-002-SS	-1.68201	-1.52786	0.15415068	0.0593	0.009141
T1BS1-BH014-002-SS	-1.65548	-1.62455	0.030930301	0.0196	0.000606
T1BS1-BH002-002-SS	-1.62455	-1.65548	-0.030930301		
T1BS1-BH009-002-SS	-1.52786	-1.68201	-0.15415068		
T1BS1-BH010-002-SS	-1.41469	-1.69282	-0.278125686		
T1BS1-BH015-002-SS	-1.28374	-1.83885	-0.555113304		
T1BS1-BH008-002-SS	-1.14885	-2.12863	-0.979778281		
T1BS1-BH012-002-SS	-1.12086	-2.20727	-1.086417016		
T1BS1-BH016-002-SS	-0.92634	-2.26336	-1.337023312		
T1BS1-BH005-002-SS	-0.82326	-3.03864	-2.215383909		

sum of b_i ($\sum b_i$) = 2.14186741
standard deviation (σ) = 0.56722194
count - 1 (n-1) = 15
W statistic = 0.951
critical value (n = 16) = 0.887
Shapiro-Wilk Test for Normality = Pass

Interpretation: The data set more closely represents a normal distribution because the calculated W statistic for the normal distribution is closer to 1.

Shapiro-Wilk Test of Normality for Background Copper at SNL/NM: Normal

Sample ID	x_i	$x_{(n-i+1)}$	$x_{(n-i+1)}-x_i$	a_{n-i+1}	b_i
T1BS1-BH013-002-SS	3.85	20.1	16.25	0.5056	8.216
T1BS1-BH015-002-SS	4.87	10.8	5.93	0.329	1.95097
T1BS1-BH009-002-SS	5.17	9.71	4.54	0.2521	1.144534
T1BS1-BH014-002-SS	6.34	9.52	3.18	0.1939	0.616602
T1BS1-BH002-002-SS	7.35	9.16	1.81	0.1447	0.261907
T1BS1-BH007-002-SS	7.58	9.13	1.55	0.1005	0.155775
T1BS1-BH004-002-SS	7.58	8.29	0.71	0.0593	0.042103
T1BS1-BH001-002-SS	7.72	7.78	0.06	0.0196	0.001176
T1BS1-BH016-002-SS	7.78	7.72	-0.06		
T1BS1-BH010-002-SS	8.29	7.58	-0.71		
T1BS1-BH003-002-SS	9.13	7.58	-1.55		
T1BS1-BH011-002-SS	9.16	7.35	-1.81		
T1BS1-BH012-002-SS	9.52	6.34	-3.18		
T1BS1-BH008-002-SS	9.71	5.17	-4.54		
T1BS1-BH006-002-SS	10.8	4.87	-5.93		
T1BS1-BH005-002-SS	20.1	3.85	-16.25		

sum of b_i ($\sum b_i$) = 12.39
standard deviation (σ) = 3.63
count - 1 (n-1) = 15
W statistic = 0.776
critical value (n = 16) = 0.887
Shapiro-Wilk Test for Normality = Fail

Shapiro-Wilk Test of Normality for Background Copper at SNL/NM: Lognormal

Sample ID	x_i	$x_{(n-i+1)}$	$x_{(n-i+1)}-x_i$	a_{n-i+1}	b_i
T1BS1-BH013-002-SS	1.35	3	1.65	0.5056	0.83424
T1BS1-BH015-002-SS	1.58	2.38	0.8	0.329	0.2632
T1BS1-BH009-002-SS	1.64	2.27	0.63	0.2521	0.158823
T1BS1-BH014-002-SS	1.85	2.25	0.4	0.1939	0.07756
T1BS1-BH002-002-SS	1.99	2.21	0.22	0.1447	0.031834
T1BS1-BH007-002-SS	2.03	2.21	0.18	0.1005	0.01809
T1BS1-BH004-002-SS	2.03	2.12	0.09	0.0593	0.005337
T1BS1-BH001-002-SS	2.04	2.05	0.01	0.0196	0.000196
T1BS1-BH016-002-SS	2.05	2.04	-0.01		
T1BS1-BH010-002-SS	2.12	2.03	-0.09		
T1BS1-BH003-002-SS	2.21	2.03	-0.18		
T1BS1-BH011-002-SS	2.21	1.99	-0.22		
T1BS1-BH012-002-SS	2.25	1.85	-0.4		
T1BS1-BH008-002-SS	2.27	1.64	-0.63		
T1BS1-BH006-002-SS	2.38	1.58	-0.8		
T1BS1-BH005-002-SS	3	1.35	-1.65		

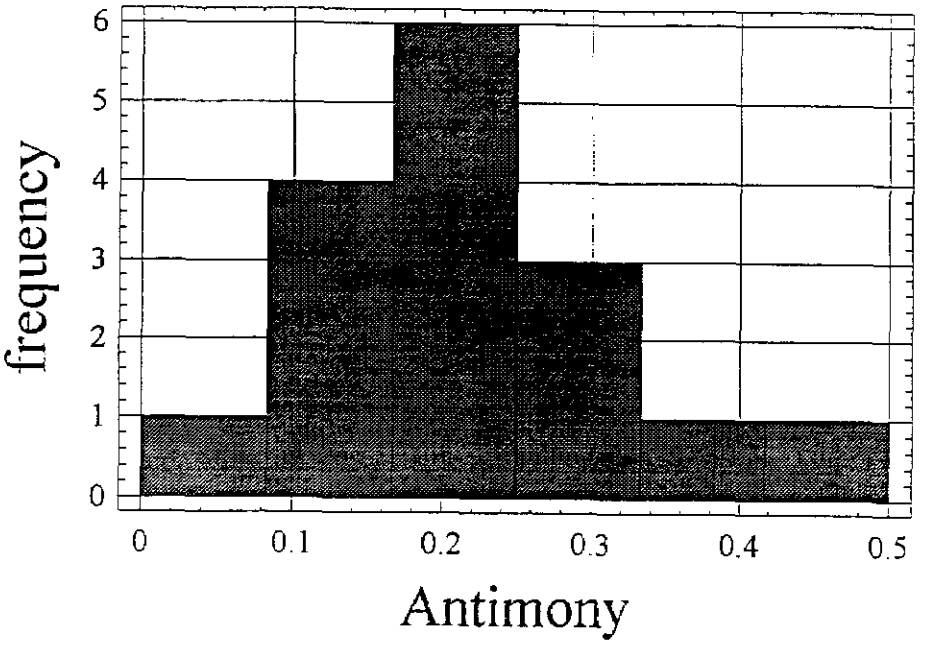
sum of b_i (Σb_i) = 1.39
standard deviation (σ) = 0.37
count - 1 (n-1) = 15
W statistic = 0. 929
critical value (n = 16) = 0.887
Shapiro-Wilk Test for Normality = Pass

Interpretation: The data set more closely represents a lognormal distribution because the calculated W statistic for the lognormal distribution passes the Shapiro-Wilk test.

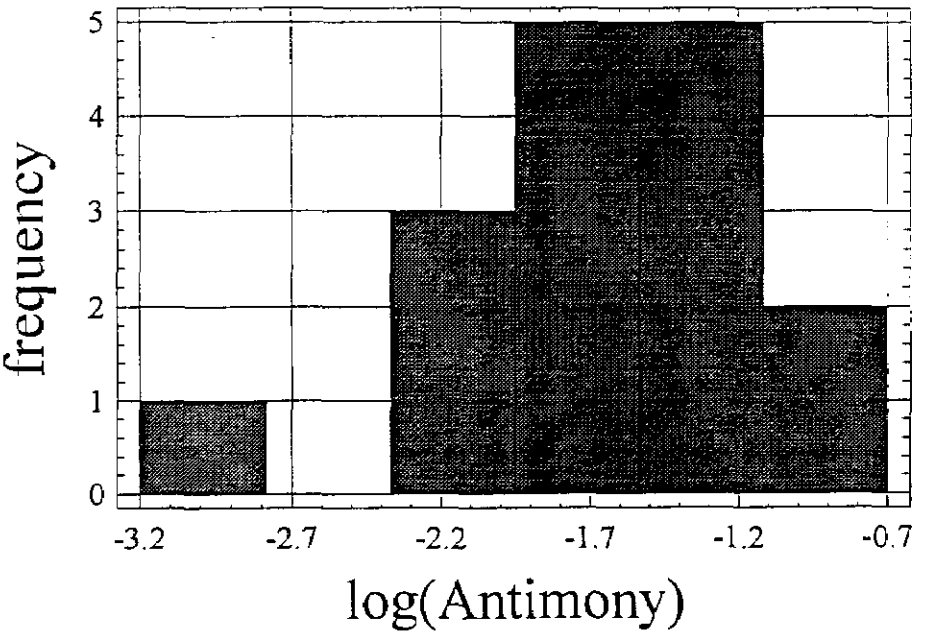
1.6 Histograms

Histograms are useful for visually determining whether the data sets are skewed, and if so, in what direction. Histograms are created by determining the range of sample concentrations, then dividing the concentration range into equal intervals. Samples are then placed into the appropriate concentration intervals. The concentration range forms the x-axis. Calculating the percentage of samples per concentration interval compared to the total number of samples, or simply plotting the number of data values that fall within an interval, provides the y-axis in terms of percent frequency or frequency, respectively, of a particular concentration interval.

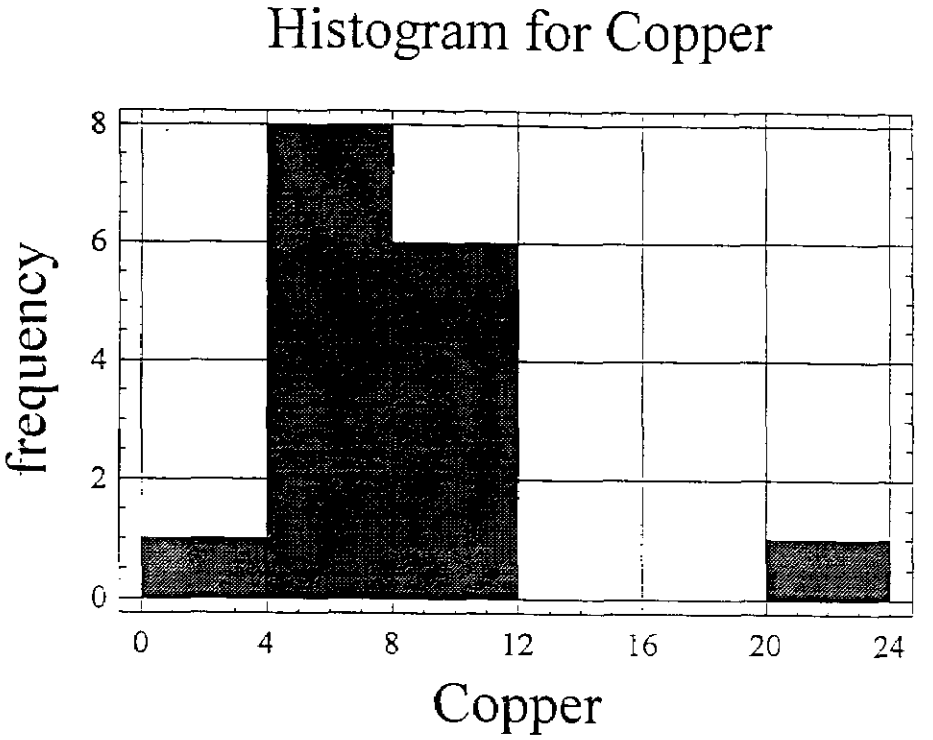
Histogram for Antimony

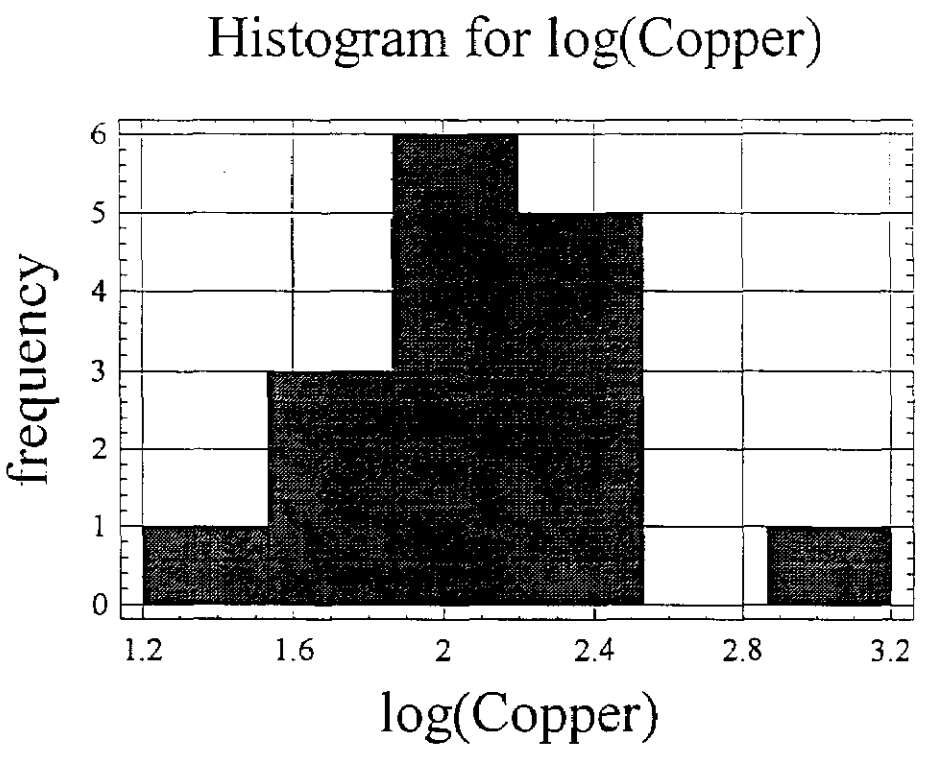


Histogram for log(Antimony)



Interpretation: The data set more closely represents a normal distribution.





Interpretation: The data set more closely represents a lognormal distribution

1.7 Probability Plots

Another simple and useful graphical test for determining normality is to plot the data on probability paper. The y-axis is scaled to represent probabilities according to the normal distribution, and the data are arranged in increasing order. An observed value is plotted on the x-axis, and the proportion of observations less than or equal to each observed value is plotted as the y-coordinate. The scale is constructed so that, if the data are normal, the points when plotted will approximate a straight line. Visually apparent curves or bends indicate that the data do not follow a normal distribution (EPA, 1992a).

Probability plots are particularly useful for spotting irregularities within the data when compared to a specific distributional model such as the normal distribution. It is easy to determine whether departures from normality are occurring more or less in the middle ranges of the data or in the extreme tails. Probability plots can also indicate the presence of possible outlier values that do not follow the basic pattern of the data and can show the presence of significant positive or negative skewness.

The probability for a particular data value x is calculated as

$$\text{Probability} = 100*((i-3/8)/(n+1/4))$$

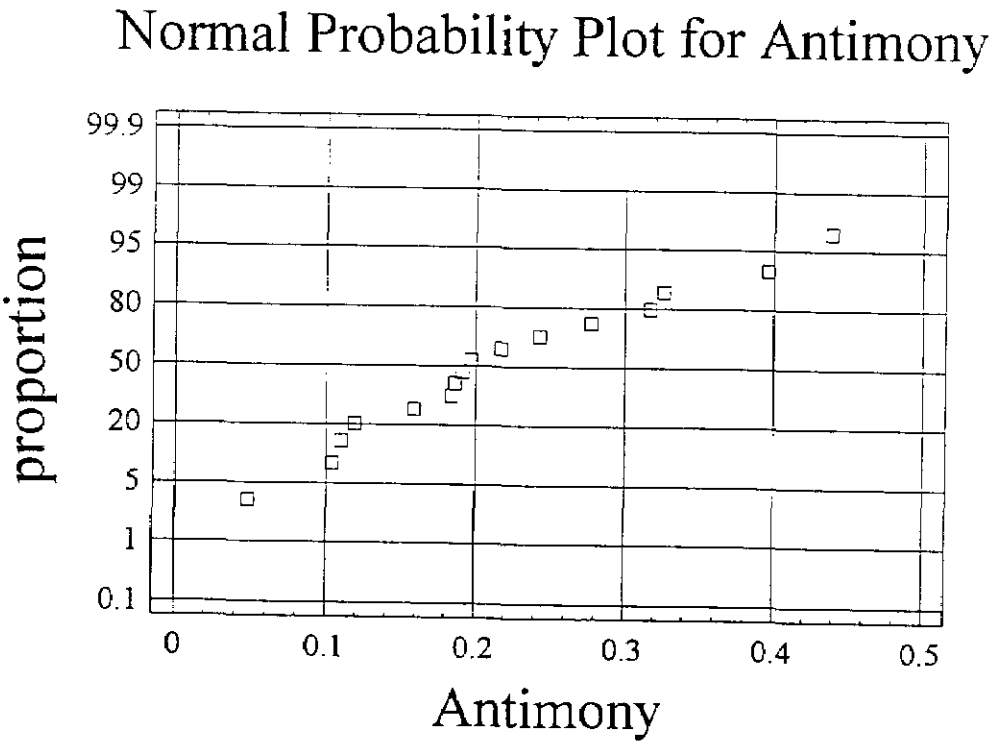
where,

i = ranked order of x_i from i to n
n = number of samples

Probability Plot for Background Antimony at SNL/NM:

Sample ID	Coded Value	Order (i)	Probability 100*((i-3/8)/(n+1/4))
T1BS1-BH001-002-SS	0.0479	1	3.846154
T1BS1-BH007-002-SS	0.104	2	10
T1BS1-BH006-002-SS	0.11	3	16.15385
T1BS1-BH013-002-SS	0.119	4	22.30769
T1BS1-BH004-002-SS	0.159	5	28.46154
T1BS1-BH011-002-SS	0.184	6	34.61538
T1BS1-BH003-002-SS	0.186	7	40.76923
T1BS1-BH014-002-SS	0.191	8	46.92308
T1BS1-BH002-002-SS	0.197	9	53.07692
T1BS1-BH009-002-SS	0.217	10	59.23077
T1BS1-BH010-002-SS	0.243	11	65.38462
T1BS1-BH015-002-SS	0.277	12	71.53846
T1BS1-BH008-002-SS	0.317	13	77.69231
T1BS1-BH012-002-SS	0.326	14	83.84615
T1BS1-BH016-002-SS	0.396	15	90
T1BS1-BH005-002-SS	0.439	16	96.15385

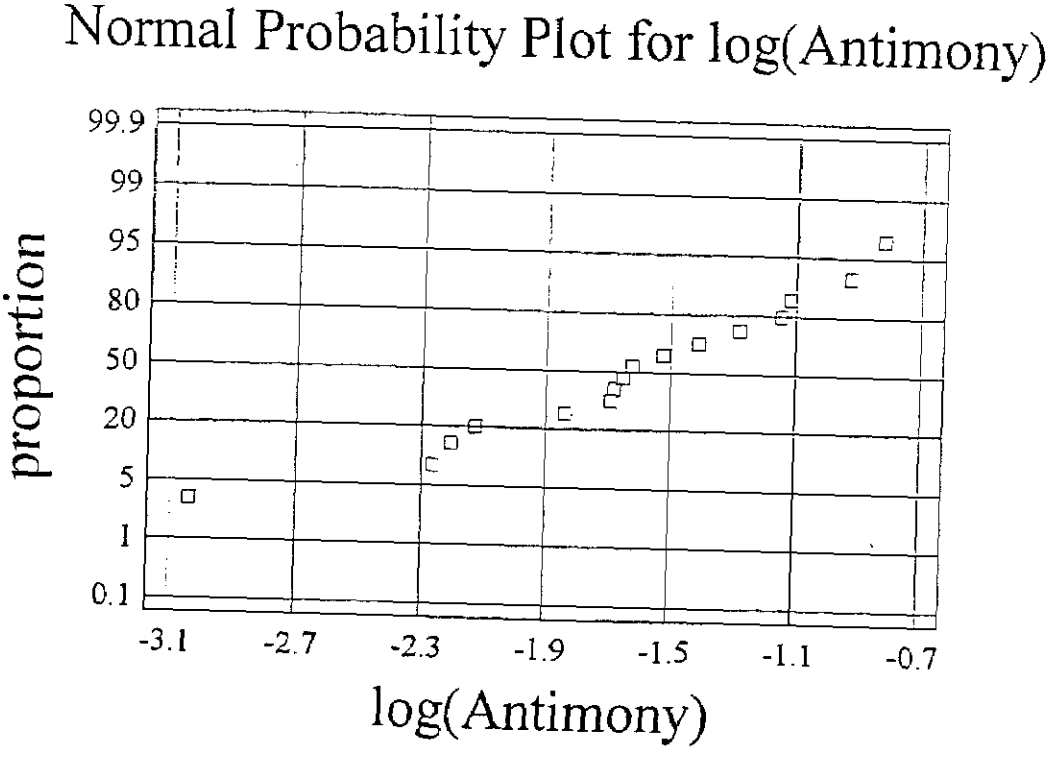
n = 16



Normal Probability Plot for Background Lognormal Antimony at SNL/NM:

Sample ID	Log (Coded Value)	Order (i)	Probability 100*((i-3/8)/(n+1/4))
T1BS1-BH001-002-SS	-3.039	1	3.846154
T1BS1-BH007-002-SS	-2.263	2	10
T1BS1-BH006-002-SS	-2.21	3	16.15385
T1BS1-BH013-002-SS	-2.129	4	22.30769
T1BS1-BH004-002-SS	-1.839	5	28.46154
T1BS1-BH011-002-SS	-1.693	6	34.61538
T1BS1-BH003-002-SS	-1.682	7	40.76923
T1BS1-BH014-002-SS	-1.655	8	46.92308
T1BS1-BH002-002-SS	-1.625	9	53.07692
T1BS1-BH009-002-SS	-1.528	10	59.23077
T1BS1-BH010-002-SS	-1.415	11	65.38462
T1BS1-BH015-002-SS	-1.284	12	71.53846
T1BS1-BH008-002-SS	-1.149	13	77.69231
T1BS1-BH012-002-SS	-1.121	14	83.84615
T1BS1-BH016-002-SS	-0.926	15	90
T1BS1-BH005-002-SS	-0.823	16	96.15385

n = 16

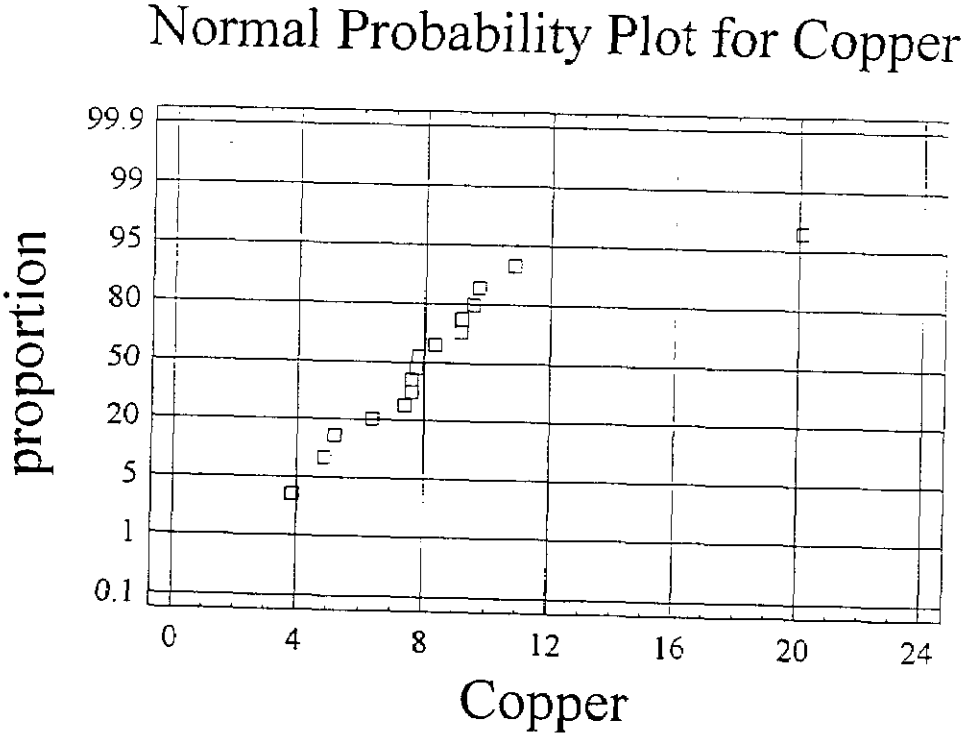


Interpretation: The data set more closely represents a normal distribution because a straight line is more easily fit on the normal distribution plot.

Probability Plot for Background Copper at SNL/NM:

Sample ID	Raw Data	Order (i)	Probability 100*((i-3/8)/(n+1/4))
T1BS1-BH013-002-SS	3.85	1	3.846153846
T1BS1-BH015-002-SS	4.87	2	10
T1BS1-BH009-002-SS	5.17	3	16.15384615
T1BS1-BH014-002-SS	6.34	4	22.30769231
T1BS1-BH002-002-SS	7.35	5	28.46153846
T1BS1-BH007-002-SS	7.58	6	34.61538462
T1BS1-BH004-002-SS	7.58	7	40.76923077
T1BS1-BH001-002-SS	7.72	8	46.92307692
T1BS1-BH016-002-SS	7.78	9	53.07692308
T1BS1-BH010-002-SS	8.29	10	59.23076923
T1BS1-BH003-002-SS	9.13	11	65.38461538
T1BS1-BH011-002-SS	9.16	12	71.53846154
T1BS1-BH012-002-SS	9.52	13	77.69230769
T1BS1-BH008-002-SS	9.71	14	83.84615385
T1BS1-BH006-002-SS	10.8	15	90
T1BS1-BH005-002-SS	20.1	16	96.15384615

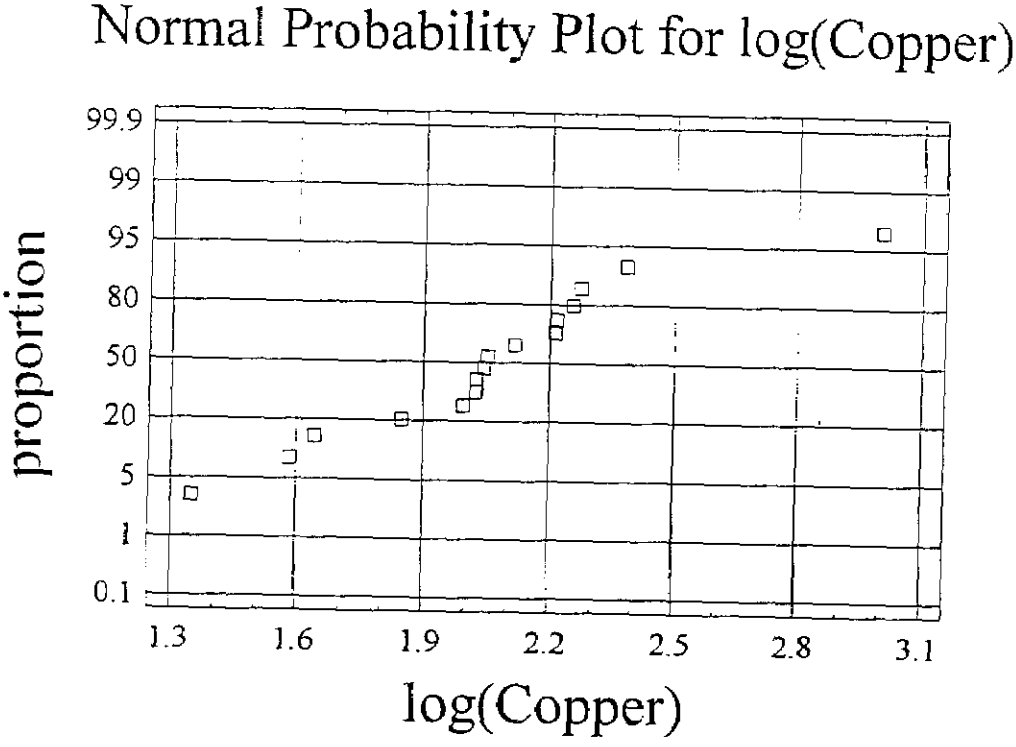
n = 16



Normal Probability Plot for Background Lognormal Copper at SNL/NM:

Sample ID	Log (Raw Data)	Order (i)	Probability 100*((i-3/8)/(n+1/4))
T1BS1-BH013-002-SS	1.348	1	3.846154
T1BS1-BH015-002-SS	1.583	2	10
T1BS1-BH009-002-SS	1.643	3	16.15385
T1BS1-BH014-002-SS	1.847	4	22.30769
T1BS1-BH002-002-SS	1.995	5	28.46154
T1BS1-BH007-002-SS	2.026	6	34.61538
T1BS1-BH004-002-SS	2.026	7	40.76923
T1BS1-BH001-002-SS	2.044	8	46.92308
T1BS1-BH016-002-SS	2.052	9	53.07692
T1BS1-BH010-002-SS	2.115	10	59.23077
T1BS1-BH003-002-SS	2.212	11	65.38462
T1BS1-BH011-002-SS	2.215	12	71.53846
T1BS1-BH012-002-SS	2.253	13	77.69231
T1BS1-BH008-002-SS	2.273	14	83.84615
T1BS1-BH006-002-SS	2.38	15	90
T1BS1-BH005-002-SS	3.001	16	96.15385

n = 16



Interpretation: The data set more closely represents a lognormal distribution because a straight line is more easily fit on the lognormal distribution plot.

1.8 Determination of Distribution

Upon completion of the *a priori* screen, percent non-detect determination, and graphical and numerical distribution analysis, a determination of the distribution was made (EPA, 1992a).

Based on the distribution analysis results, antimony was determined to be normally distributed and copper was determined to be lognormally distributed for the SNL/NM background data set.

Determination of the distribution type is not always as simple as the examples presented above. The Shapiro-Wilk Test of Normality is the most powerful of the distribution tests. If the data fail the Shapiro-Wilk Test, they were considered to be non-parametric. If the data set passed the Shapiro-Wilk test, but failed other tests, the statistician must make a professional judgment concerning the distribution type.

1.9 The T_n Statistic Test

The T_n Statistic test was performed on SNL/NM background data after the *a priori* screen and initial distribution analysis had been completed. The test was run iteratively until the largest remaining value in the data set passed. If a particular data set had fewer than 15% non-detects but failed the parametric distribution tests, it was often carried over to the T_n Statistic and analyzed using the parametric distribution that it most closely resembled. In some instances, identification and removal of outliers during the T_n Statistic procedure allows for the previously failed data set to pass the parametric numerical and graphical tests. If failures were reported during the T_n statistical test, the values were removed and the mean and standard deviation were recalculated on the censored data set. Failures of the T_n Statistic are defined as T_n calculated values that exceed the critical value (EPA, 1989). The censored data set was then used for all additional statistical tests. (Removed data points are considered either potential sampling error, laboratory error, an anomalously high value, or some other factor contributing to an unexpectedly large concentration).

To calculate the T_n statistic, the following formula is used:

$$T_n = \frac{(x_n - \bar{x})}{\sigma}$$

where

$T_n = T_n$ statistic,
X_n = individual sample,
$\bar{x}$ = mean of sample set, and
σ = standard deviation.

T_n statistic for Antimony:

$$T_{16} = \frac{(0.439 - 0.22)}{0.11}$$

$$T_{16} = 1.99$$

According to Table 8 in Appendix B of EPA's guidance document (EPA, 1992a), when the T_n statistic is larger than the Critical Number (C_n), provided in the table for that sample size, then the number should be considered an outlier. In this case, $C_{16} = 2.443$,

$$T_{16}(1.99) < C_{16}(2.443),$$

and thus, no data points needed to be removed.

T_n statistic for Copper:

$$T_{16} = \frac{(3.00 - 2.06)}{0.37}$$

$$T_{16} = 2.54$$

$$T_{16}(2.54) > C_{16}(2.443)$$

So this data value (3.00) was removed from the data set and the mean and standard deviation were recalculated.

New mean = 2.00
New standard deviation = 0.29

$$T_{15} = \frac{(2.38 - 2.00)}{0.29}$$

$$T_{15} = 1.31$$

$$T_{15}(1.31) < C_{15}(2.41)$$

Therefore, no additional data points were removed.

1.10 Determination of Maximum Expected Background Concentration

This section describes two methods, one for parametric data and the other for non-parametric data, that establish the maximum expected background concentration using a 95 percent confidence limit. An upper tolerance limit (Section 1.10.1) is calculated for parametric data sets, while a 95th percentile (Section 1.10.2) is calculated for non-parametric data sets.

1.10.1 Upper Tolerance Limits

A tolerance interval establishes a concentration range that is constructed to contain a specified proportion (P%) of the population with a specified confidence coefficient, Y. The proportion of the population included, P, is referred to as the coverage. The probability with which the tolerance interval includes the proportion P% of the population is referred to as the tolerance coefficient.

A coverage of 95% was used as recommended by EPA (1989). By using this coverage, random observations from the same distribution as the SNL/NM background soil data would exceed the upper tolerance limit less than 5% of the time. Similarly, a tolerance coefficient of 95% was used. This means that there is a confidence level of 95% that the upper 95% tolerance limit would contain at least 95% of the distribution of observations from background soil data. These values were chosen to be consistent with the performance standards described in Section 2 of EPA 1989.

Tolerance intervals were constructed assuming that the data or the transformed data were normally distributed.

The formula for the UTL is as follows:

$$TL = \bar{x} + t_{.05(n-1)} \bullet \sigma$$

where

$\bar{x}$ = the mean of the population,
$t_{.05(n-1)}$ is one-sided tolerance factor for n (Table 5, Appendix B, EPA 1989), and
σ = the standard deviation

For Antimony,

$$UTL = 0.22 + t_{.05}(0.11)$$

$$= 0.22 + 2.523(0.11)$$

$$UTL = 0.50$$

For copper,

$$UTL = e(2.00 + t_{.05}(0.29))$$

$$= e(2.00 + 2.566(0.29))$$

$$UTL = 15.55$$

Note: Since the data values are log-transformed, they must be transformed back to complete the UTL calculation.

1.10.2 95th Percentile

For non-parametric data sets, the 95th percentile value was used for expressing the upper range of background. The 95th percentile indicated that 95 percent of the data would be expected to be below that value, while 5 percent would be above the value. The calculated background was therefore insensitive to the magnitude of the largest 5 percent of the data points.

The 95th percentile value was taken to be the observation point closest to 0.95 (n+1), where p = percentile of interest (95th) and **n** = number of samples. For data sets with **n**<20, the 95th percentile was taken to be the maximum data value.

2. Comparison Tests

2.1 Introduction

Comparison tests were performed between SNL/NM background and ER site-specific data to determine if the two data sets were statistically similar. If the data sets were similar, then contamination would assumed to be absent. If the ER site-specific data were not statistically similar to the background data, then contamination might exist.

Comparison tests are of two basic types: parametric and non-parametric. The parametric tests are only applied to data sets in which the background data set was shown to be parametric. Parametric tests include the F distribution and the Student's t-test for equal and non-equal variances. Non-parametric tests are applied to all data sets. Non-parametric tests include the Wilcoxon Rank-sum test and the Quantile test.

The following sections provide example calculations for parametric and non-parametric comparison tests. The normally distributed antimony data presented in Section 1 serves as the background data set. Two imaginary data sets (ER Site A and ER Site B) were used to represent sites at which contamination may exist. The data set for ER Site A is designed to be statistically similar to background, while that for ER Site B is designed to be statistically dissimilar from background.

2.2 Parametric Comparison Tests

The following sections provide example calculations of the F distribution and the Student's t-test (with both equal and non-equal variances).

2.2.1 F Distribution

The F distribution is a parametric statistical method for comparing population variances. The determination of like variances is important in terms of identifying which Student's t-test method is appropriate for evaluation. If the variances of two data sets were found to be statistically similar, the Student's t-test for equal variances was used. If the variances of the data set were not statistically similar, then the Student's t-test for unequal variances was used.

The F distribution is calculated as follows:

$$F = \frac{S_1^{\,2}}{S_2^{\,2}}$$

where

F = F distribution calculated value,
$S_1^{\,2}$ = sample variance of population 1, and
$S_2^{\,2}$ = sample variance of population 2.

Note: Always place the larger sample variance in the numerator of the equation.

F Distribution Comparing SNL/NM Background to ER Site A:

Background variance = 0.011
ER Site A variance = 0.010

$$\text{So} \quad F = \frac{0.011}{0.010}$$

$$F = 1.10$$

The critical value was determined from Table 6 in Appendix 11 in Mendenhall (1975). Because it was a two-sided test, the confidence level was reduced from 95% to 90%. The critical value for 15 degrees of freedom for both background and ER Site B was 2.40.

Interpretation: Since F(1.09) < critical value (2.40), there was insufficient statistical evidence to indicate a difference in the population variances.

F Distribution Comparing SNL/NM Background to ER Site B:

Background variance = 0.011
ER Site B variance = 0.014

$$\text{So} \quad F = \frac{0.014}{0.011}$$

$$F = 1.27$$

The critical value was determined from Table 6 in Appendix 11 in Mendenhall (1975). Because it was a two-sided test, the confidence level was reduced from 95% to 90%. The critical value for 15 degrees of freedom for both background and ER Site B was 2.40.

Interpretation: Since F(1.25) < critical value (2.40), there was insufficient statistical evidence to indicate a difference in the population variances.

2.2.2 Student's t-test

The t-test is a parametric test that compares the means of two samples. To use the t statistic, both sampled populations must be approximately the same normally or lognormally distributed, and the random samples must be selected independently of each other (Steel and Torrie, 1980). Methods are provided for calculating the t-test with both equal and non-equal variances.

Student's t-test with equal variances

SNL/NM Background versus ER Site A:

BK*	$(BK)^2$	ER-A**	$(ER-A)^2$
0.439	0.192721	0.426	0.181476
0.396	0.156816	0.401	0.160801
0.326	0.106276	0.318	0.101124
0.317	0.100489	0.302	0.091204
0.277	0.076729	0.284	0.080656
0.243	0.059049	0.279	0.077841
0.217	0.047089	0.216	0.046656
0.197	0.038809	0.182	0.033124
0.191	0.036481	0.181	0.032761
0.186	0.034596	0.176	0.030976
0.184	0.033856	0.174	0.030276
0.159	0.025281	0.160	0.025600
0.119	0.014161	0.130	0.016900
0.110	0.0121	0.118	0.013924
0.104	0.010816	0.100	0.010000
0.0479	0.00229441	0.090	0.008100

* BK = Background Concentration
** ER-A = ER Site A Concentration

Mean =	0.22		0.221	
Variance =	0.011		0.010	
Count (n) =	16		16	
Sum of BK =	3.513	Sum of $(BK)^2 = 0.948$	3.537	Sum of $(ER-A)^2 = 0.941$

where

$n_1=n_2=n$ (this equality is not a requirement of the test),
S^2 = sample variance, and
df = degrees of freedom.

$$\sum Y_1^2 - \frac{(\sum Y_1)^2}{n} = 0.948 - \frac{(3.513)^2}{16} = 0.177$$

$$\sum Y_2^2 - \frac{(\sum Y_2)^2}{n} = 0.941 - \frac{(3.537)^2}{16} = 0.159$$

$$S^2 = \frac{\sum Y_1^2 - \frac{(\sum Y_1)^2}{n} + \sum Y_2^2 - \frac{(\sum Y_2)^2}{n}}{2(n-1)}$$

$$S^2 = \frac{0.177 + 0.159}{2(16-1)} = \frac{0.336}{30} = 0.0112$$

which is an estimate of the common σ^2. The degrees of freedom, df, are calculated as

df = 2(n-1)
df = 2(16-1) = 30.

$$S_{\bar{Y}_1 - \bar{Y}_2} = \sqrt{\frac{2S^2}{n}} = \sqrt{\frac{2(0.0112)}{16}} = \sqrt{0.0014} = 0.037,$$

which is the standard deviation appropriate to the difference between sample means.

$$t = \frac{\overline{Y}_1 - \overline{Y}_2}{S_{\overline{Y}_1 - \overline{Y}_2}} = \frac{0.22 - 0.221}{0.037} = -0.027$$

tabulated t for df = 30 is 2.042 for = 95 percent confidence

To determine if the observed difference between means was significant, the 95 percent confidence interval was calculated. The means were approximately equal if the 95 percent confidence interval spanned zero.

For the 95th percent confidence interval...

$$\overline{Y}_2 - \overline{Y}_1 \pm t_{.025}^{*} S_{\overline{Y}_1 - \overline{Y}_2}$$

$$= +.001 \pm 2.042(.037)$$

$$= +.001 \pm .0756$$

$$= .0766 \text{ to } -0.0746$$

* for a two-tailed test

Interpretation: Since the 95 percent confidence interval spanned zero, the means were approximately equal. The calculated t was within the ± range of the tabulated t, also indicating that the means were approximately equal.

Note: if n was not equal between SNL/NM background and the ER Site, a variation of $S_{\overline{Y}_1 - \overline{Y}_2}$ is

$$S_{\overline{Y}_1 - \overline{Y}_2} = \sqrt{S^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)} = \sqrt{S^2\left(\frac{n_1 + n_2}{n_1 n_2}\right)}$$

where S^2 is the weighted average of the sample variances, calculated as

$$S^2 = \frac{(n_1 - 1)S_1^{\,2} + (n_2 - 1)S_2^{\,2}}{(n_1 - 1) + (n_2 - 1)}$$

SNL/NM Background versus ER Site B ($n_1 = n_2 = n$):

BK*	$(BK)^2$	ER-B**	$(ER\text{-}B)^2$
0.439	0.192721	0.632	0.399424
0.396	0.156816	0.610	0.3721
0.326	0.106276	0.589	0.346921
0.317	0.100489	0.562	0.315844
0.277	0.076729	0.545	0.297025
0.243	0.059049	0.519	0.269361
0.217	0.047089	0.501	0.251001
0.197	0.038809	0.491	0.241081
0.191	0.036481	0.461	0.212521
0.186	0.034596	0.421	0.177241
0.184	0.033856	0.383	0.146689
0.159	0.025281	0.361	0.130321
0.119	0.014161	0.312	0.097344
0.110	0.0121	0.300	0.090000
0.104	0.010816	0.296	0.087616
0.0479	0.00229441	0.250	0.0625

* BK = Background Concentration
** ER-B = ER Site B Concentration

Mean =	0.22		0. 452	
Variance =	0.011		0. 014	
Count (n) =	16		16	
Sum of BK =	3.513	Sum of $(BK)^2 = 0.948$	7.233	Sum of $(ER\text{-}B)^2 = 3.497$

where

$n_1=n_2=n$ (this equality is not a requirement of the test),
S^2 = sample variance, and
df = degrees of freedom.

$$\sum Y_1^2 - \frac{(\sum Y_1)^2}{n} = 0.948 - \frac{(3.513)^2}{16} = 0.177$$

$$\sum Y_2^2 - \frac{(\sum Y_2)^2}{n} = 3.497 - \frac{(7.233)^2}{16} = 0.227$$

$$S^2 = \frac{\sum Y_1^2 - \frac{(\sum Y_1)^2}{n} + \sum Y_2^2 - \frac{(\sum Y_2)^2}{n}}{2(n-1)}$$

$$S^2 = \frac{0.177 + 0.227}{2(16-1)} = \frac{0.404}{30} = 0.0135$$

which is an estimate of the common σ^2

$$df = 2(16\text{-}1) = 30$$

$$S_{\bar{Y}_1 - \bar{Y}_2} = \sqrt{\frac{2S^2}{n}} = \sqrt{\frac{2(0.0135)}{16}} = \sqrt{0.00169} = 0.0411$$

which is the standard deviation appropriate to the difference between sample means.

$$t = \frac{\bar{Y}_1 - \bar{Y}_2}{S_{\bar{Y}_1 - \bar{Y}_2}} = \frac{0.22 - 0.452}{0.0411} = -5.64$$

tabulated t for df = 30 is 2.042 for 95 percent confidence

To determine if the observed difference between means was significant, the 95 percent confidence interval was calculated. The means were approximately equal if the 95 percent confidence interval contained zero.

For the 95th percent confidence interval

$$\overline{Y}_2 - \overline{Y}_1 \pm t_{.025}{}^{*} S_{\overline{Y}_1 - \overline{Y}_2}$$

$$= 0.232 \pm 2.042(.0411)$$

$$= 0.232 \pm .0839$$

$$= .316 \text{ to } 0.148$$

* for a two-tailed test

Interpretation: Since the 95 percent confidence interval did not contain zero, the means were not approximately equal. The calculated t was outside the ± range of the calculated t, also suggesting that the means were not approximately equal.

Student's t-test with non-equal variances (t')

Note: though the variances are shown to be similar in Section 2.2.1, calculation of the Student's t-test was performed assuming non-equal variances for example purposes.

SNL/NM Background versus ER Site A (n_1=n_2=n):

BK*	$(BK)^2$	ER-A**	$(ER\text{-}A)^2$
0.439	0.192721	0.426	0.181476
0.396	0.156816	0.401	0.160801
0.326	0.106276	0.318	0.101124
0.317	0.100489	0.302	0.091204
0.277	0.076729	0.284	0.080656
0.243	0.059049	0.279	0.077841
0.217	0.047089	0.216	0.046656
0.197	0.038809	0.182	0.033124
0.191	0.036481	0.181	0.032761
0.186	0.034596	0.176	0.030976
0.184	0.033856	0.174	0.030276
0.159	0.025281	0.160	0.025600
0.119	0.014161	0.130	0.016900
0.110	0.0121	0.118	0.013924
0.104	0.010816	0.100	0.010000
0.0479	0.00229441	0.090	0.008100

* BK = Background Concentration
** ER-A = ER Site A Concentration

Mean =	0.22		0. 221	
Variance =	0.011		0. 010	
Count (n) =	16		16	
Sum of BK =	3.513	Sum of $(BK)^2 = 0.948$	3.537	Sum of $(ER\text{-}A)^2 = 0.941$

where

$n_1 = n_2 = n$ (this equality is not a requirement of the test),
S^2 = sample variance, and
df = degrees of freedom.

$$\sum (Y_1 - \bar{Y}_1)^2 = \sum Y_1^2 - \frac{(\sum Y_1)^2}{n} = 0.948 - \frac{(3.513)^2}{16} = 0.177$$

$$S_1^2 = \frac{\sum (Y_1 - \bar{Y}_1)^2}{n_1 - 1} = \frac{0.177}{16 - 1} = 0.0118$$

$$\sum (Y_2 - \bar{Y}_2)^2 = \sum Y_2^2 - \frac{(\sum Y_2)^2}{n} = 0.941 - \frac{(3.557)^2}{16} = 0.159$$

$$S_2^2 = \frac{\sum (Y_2 - \bar{Y}_2)^2}{n_2 - 1} = \frac{0.159}{16 - 1} = 0.0106$$

$$S_{\bar{Y}_1 - \bar{Y}_2} = \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} = \sqrt{\frac{0.0118}{16} + \frac{0.0106}{16}} = \sqrt{0.0014} = 0.037$$

$$t' = \frac{\bar{Y}_1 - \bar{Y}_2}{S_{\bar{Y}_1 - \bar{Y}_2}} = \frac{0.22 - 0.221}{0.037} = -0.027$$

$$\text{effective df} = \frac{(\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2})^2}{\frac{(\frac{S_1^2}{n_1})^2}{n_1 - 1} + \frac{(\frac{S_2^2}{n_2})^2}{n_2 - 1}} = \frac{(\frac{0.0118}{16} + \frac{0.0106}{16})^2}{\frac{(\frac{0.0118}{16})^2}{15} + \frac{(\frac{.0106}{16})^2}{15}}$$

$$= \frac{(0.0014)^2}{0.000000036 + 0.000000029}$$

$$= \frac{0.00000196}{0.000000065}$$

$$= 30.15$$

$$\approx 30$$

Interpretation: Compare t' with tabulated t for df = 30 of 2.042 for 95 percent confidence. The calculated t' was within the ± range of the tabulated t indicating that the means were approximately equal.

SNL/NM Background versus ER Site B ($n_1=n_2=n$):

BK*	$(BK)^2$	ER-B**	$(ER-B)^2$
0.439	0.192721	0.632	0.399424
0.396	0.156816	0.610	0.3721
0.326	0.106276	0.589	0.346921
0.317	0.100489	0.562	0.315844
0.277	0.076729	0.545	0.297025
0.243	0.059049	0.519	0.269361
0.217	0.047089	0.501	0.251001
0.197	0.038809	0.491	0.241081
0.191	0.036481	0.461	0.212521
0.186	0.034596	0.421	0.177241
0.184	0.033856	0.383	0.146689
0.159	0.025281	0.361	0.130321
0.119	0.014161	0.312	0.097344
0.110	0.0121	0.300	0.090000
0.104	0.010816	0.296	0.087616
0.0479	0.00229441	0.250	0.0625

* BK = Background Concentration
** ER-B = ER Site B Concentration

Mean =	0.22		0. 452	
Variance =	0.011		0. 014	
Count (n) =	16		16	
Sum of BK =	3.513	Sum of $(BK)^2 = 0.948$	7.233	Sum of $(ER-B)^2 = 3.497$

where

$n_1 = n_2 = n$ (this equality is not a requirement of the test.)
S^2 = sample variance
df = degrees of freedom

$$\sum (Y_1 - \bar{Y}_1)^2 = \sum Y_1^2 - \frac{(\sum Y_1)^2}{n} = 0.948 - \frac{(3.513)^2}{16} = 0.177$$

$$S_1^2 = \frac{\sum (Y_1 - \bar{Y}_1)^2}{n_1 - 1} = \frac{0.177}{16 - 1} = 0.0118$$

$$\sum (Y_2 - \bar{Y}_2)^2 = \sum Y_2^2 - \frac{(\sum Y_2)^2}{n} = 3.497 - \frac{(7.233)^2}{16} = 0.227$$

$$S_2^2 = \frac{\sum (Y_2 - \bar{Y}_2)^2}{n_2 - 1} = \frac{0.227}{16 - 1} = 0.0151$$

$$S_{\bar{Y}_1 - \bar{Y}_2} = \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} = \sqrt{\frac{0.0118}{16} + \frac{0.0151}{16}} = \sqrt{0.00168125} = 0.041$$

$$t' = \frac{\bar{Y}_1 - \bar{Y}_2}{S_{\bar{Y}_1 - \bar{Y}_2}} = \frac{0.22 - 0.452}{0.041} = -5.66$$

$$\text{effective df} = \frac{(\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2})^2}{\frac{(\frac{S_1^2}{n_1})^2}{n_1 - 1} + \frac{(\frac{S_2^2}{n_2})^2}{n_2 - 1}} = \frac{(\frac{0.0118}{16} + \frac{0.0151}{16})^2}{\frac{(\frac{0.0118}{16})^2}{15} + \frac{(\frac{.0151}{16})^2}{15}}$$

$$= \frac{(0.00168125)^2}{0.000000036 + 0.000000059}$$

$$= \frac{0.00000283}{0.000000095}$$

$$= 29.8$$

$$\approx 30$$

Interpretation: Compare t' with tabulated t for df = 30 of 2.042 for 95 percent confidence. The calculated t' was not within the ± range of the tabulated t indicating that the means were not approximately equal.

2.3 Non-parametric Comparison Tests

The following sections provide example calculations for the Wilcoxon-Rank Sum test and the Quantile test.

2.3.1 Wilcoxon Rank Sum Test

The Wilcoxon-Rank Sum (WRS) Test is a nonparametric test more powerful than the Quantile test to detect when the ER site-specific area has concentrations uniformly higher than background (EPA 1992b). However, the WRS test allows for fewer less-than measurements than the Quantile test. As a general rule, the WRS test should be avoided if more than about 40% of the measurements in either the potentially contaminated area or background are non-detects. All data were subjected to the WRS test in this analysis with the knowledge that the test power was greatly reduced when the non-detect percent was greater than 40.

The WRS test was performed by first ordering all observations from SNL/NM background and the ER site from lowest to highest according to their magnitude and ranked. The ranks in the potentially contaminated area were summed and compared to a table of critical values to determine whether the site was potentially contaminated.

Wilcoxon-Rank *Sum* Calculation for SNL/NM Background and ER Site A:

Background		ER Site A	
Value	**Rank**	**Value**	**Rank**
0.439	32		
		0.426	31
		0.401	30
0.396	29		
0.326	28		
		0.318	27
0.317	26		
		0.302	25
		0.284	24
		0.279	23
0.277	22		
0.243	21		
0.217	20		
		0.216	19
0.197	18		
0.191	17		
0.186	16		
0.184	15		
		0.182	14
		0.181	13
		0.176	12
		0.174	11
		0.16	10
0.159	9		
		0.13	8
0.119	7		
		0.118	6
0.11	5		
0.104	4		
		0.1	3
		0.09	2
0.0479	1		

Sum of Ranks for Site A = 258

$$Zrs = \frac{Wrs - \frac{n(N+1)}{2}}{\left[\frac{mn(N+1)}{12}\right]^{1/2}}$$

where

Wrs = sum of ranks,
m = number of background samples (16),
n = number of ER Site A samples (16), and
N = number of total samples (32).

$$Zrs = \frac{258 - \frac{16(32+1)}{2}}{\left[\frac{(16)(16)(32+1)}{12}\right]^{1/2}} = \frac{-6}{\sqrt{704}}$$

$$Zrs = \frac{258 - 264}{\left[\frac{(256)(33)}{12}\right]^{1/2}} = \frac{-6}{\sqrt{704}}$$

$$Zrs = \frac{-6}{[704]^{1/2}} = \frac{-6}{\sqrt{704}}$$

$$Zrs = \frac{-6}{26.5} = \frac{-6}{\sqrt{704}}$$

$$Zrs = -0.23 = -0.226\ (-0.23)$$

This formula is applicable only when there are no ties in data values between background and ER Site data. If value ties exist, use formula 6.13 on page 6.11 of EPA (1992b).

Critical value $Z_{0.95} = 1.645$, so $-0.23 < 1.645$: $-0.23 < 1.645$

Interpretation: There was no statistical evidence that ER Site A is contaminated.

Wilcoxon-Rank Sum Calculation for SNL/NM Background and ER Site B:

Background		ER Site B	
Value	Rank	Value	Rank
		0.632	32
		0.61	31
		0.589	30
		0.562	29
		0.545	28
		0.519	27
		0.501	26
		0.491	25
		0.461	24
0.439	23		
		0.421	22
0.396	21		
		0.383	20
		0.361	19
0.326	18		
0.317	17		
		0.312	16
		0.3	15
		0.296	14
0.277	13		
		0.25	12
0.243	11		
0.217	10		
0.197	9		
0.191	8		
0.186	7		
0.184	6		
0.159	5		
0.119	4		
0.11	3		
0.104	2		
0.0479	1		

Sum of Ranks for Site B = 370

$$Zrs = \frac{Wrs - \frac{n(N+1)}{2}}{\left[\frac{mn(N+1)}{12}\right]^{1/2}}$$

where...

Wrs = sum of ranks,
m = number of background samples (16),
n = number of ER Site A samples (16), and
N = number of total samples (32).

$$Zrs = \frac{370 - \frac{16(32+1)}{2}}{\left[\frac{(16)(16)(32+1)}{12}\right]^{1/2}}$$

$$Zrs = \frac{370 - 264}{\left[\frac{(256)(33)}{12}\right]^{1/2}}$$

$$Zrs = \frac{106}{[704]^{1/2}}$$

$$Zrs = \frac{106}{26.5}$$

$$Zrs = 4.0$$

This formula is applicable only when there are no ties in data values between background and ER Site data. If value ties exist, use formula 6.13 on page 6.11 of EPA (1992b).

Critical value = $Z_{0.95}$ = 1.645, so 4.0 > 1.645

Interpretation: There was statistical evidence that ER Site B is contaminated.

2.3.2 The Quantile Test

The Quantile Test is statistically more powerful than the WRS test for determining whether a discrete portion of the site is contaminated. Initially, the data values from the background set and from the ER site-specific data set are ranked from highest to lowest. An evaluation was made of the number of measurements among the maximum concentrations within the combined data set that were from the ER site-specific data set. If the count was sufficiently large, then it was concluded that the ER site might actually be contaminated.

After the data values were ranked, Table A.8 (EPA, 1992b) was referenced to evaluate how many of the maximum values must come from the ER site to classify it as being contaminated. The table lists the number of samples from the ER site along the top, and the number of samples from SNL/NM background along the left side. The row and column was followed into the table, and where they met was where the determination was made. The table is segmented into increments of 5; the value was rounded up one level if the number did not fall on a multiple of 5. In our example, there were 16 samples from the ER site data set and 16 samples from the background data set. For the ER site, the number was read from Column 20, and the background reading was read from Row 20, producing the reading 4,4. This indicated that the first four numbers from the ER site must be higher than any numbers from the background data set.

Quantile Test Comparison between SNL/NM Background and ER Site A Antimony Concentrations:

Background	ER Site A
0.439	0.426
0.396	0.401
0.326	0.318
0.317	0.302
0.277	0.284
0.243	0.279
0.217	0.216
0.197	0.182
0.191	0.181
0.186	0.176
0.184	0.174
0.159	0.16
0.119	0.13
0.11	0.118
0.104	0.1
0.0479	0.09

Interpretation: Only 2 of the 4 maximum values came from ER Site A. Therefore, contamination was not indicated.

Quantile Test Comparison between SNL/NM Background and ER Site B Antimony Concentrations:

Background	ER Site B
0.439	0.632
0.396	0.61
0.326	0.589
0.317	0.562
0.277	0.545
0.243	0.519
0.217	0.501
0.197	0.491
0.191	0.461
0.186	0.421
0.184	0.383
0.159	0.361
0.119	0.312
0.11	0.3
0.104	0.296
0.0479	0.25

Interpretation: Since the 4 maximum values were all from ER Site B, contamination was indicated.

2.4 Results of the Comparison Tests

ER Site A was statistically similar to SNL/NM background in all statistically performed calculations. Therefore, there is no statistical evidence to indicate that ER Site A is contaminated.

ER Site B was not statistically similar to SNL/NM background. Failures of the Student's t-test, the Wilcoxon Rank-Sum test and the Quantile test indicated that ER Site B is contaminated.

Commonly, the determination of contamination at ER sites is not as simple as the above examples. EPA (1992b) guidance suggests that all soil data be subjected to the Wilcoxon Rank-Sum test and the Quantile test. Therefore, if either of these tests fail, the ER site is considered to be contaminated. If both of these tests pass, but other applicable tests fail, the statistician must make a professional judgment as to whether contamination exists at the ER site.

When background data sets were collected at different areas within a Technical Area or pertinent region, or when background samples were collected at varying depths, it was sometimes appropriate to determine if the background data sets were statistically similar.

The most powerful of the background statistical tests is the Wilcoxon Rank-Sum test. If the background data sets passed the Wilcoxon Rank-Sum test, the data sets were considered statistically similar. If normality could be assumed, probability plots were also constructed from the combined sets, which provided a second set of comparison tests.

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APPENDIX G
CONFIRMATORY GAMMA SPECTROSCOPIC ANALYSES FOR RADIATION ANOMALY REMOVAL ACTION (ELECTRONIC)

Plate 1. Aerial Photography Interpretation in Technical Areas III and V.

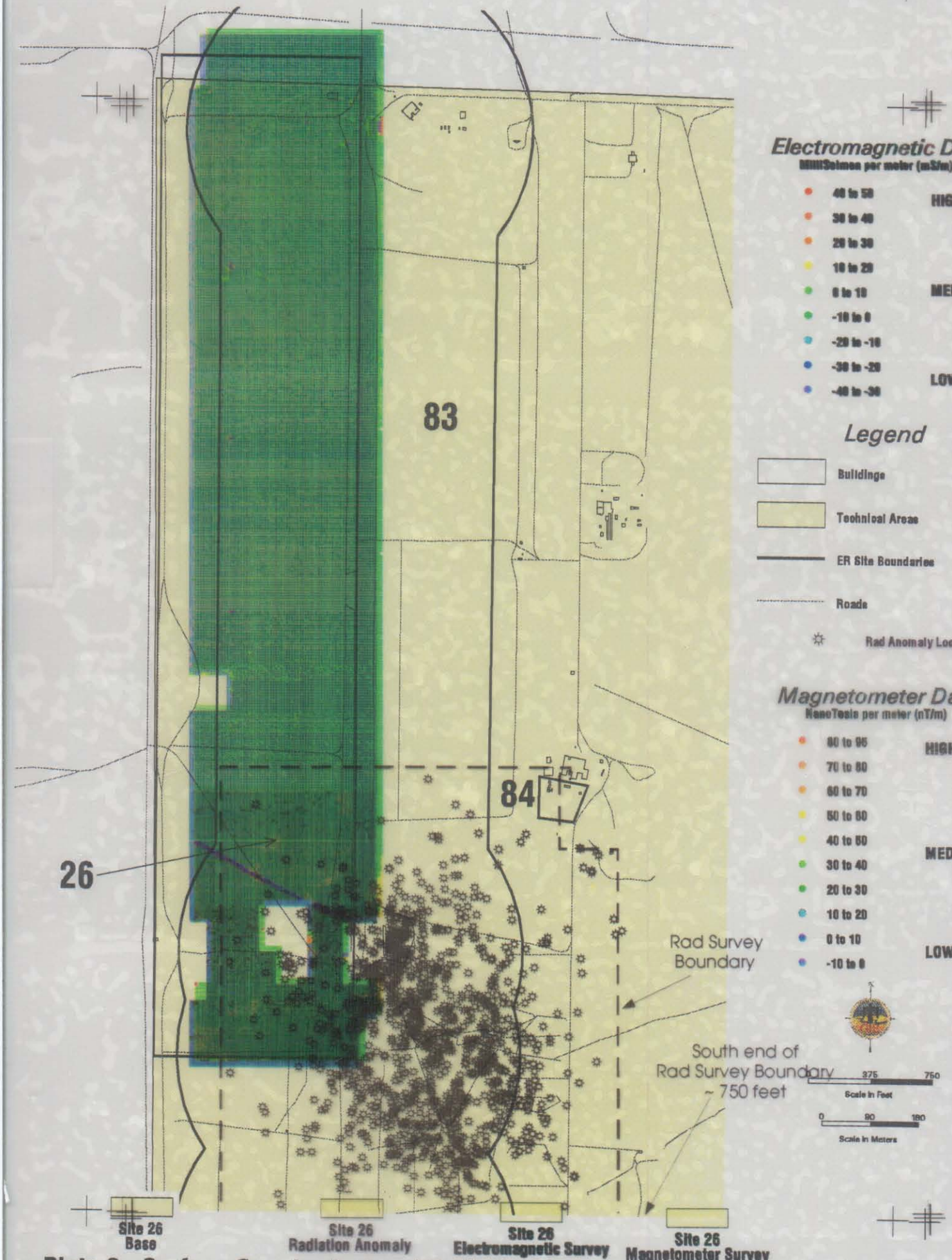

Plate 2. Surface Geophysical and Radiation Surveys at ER Sites 26 and 83, Technical Area III

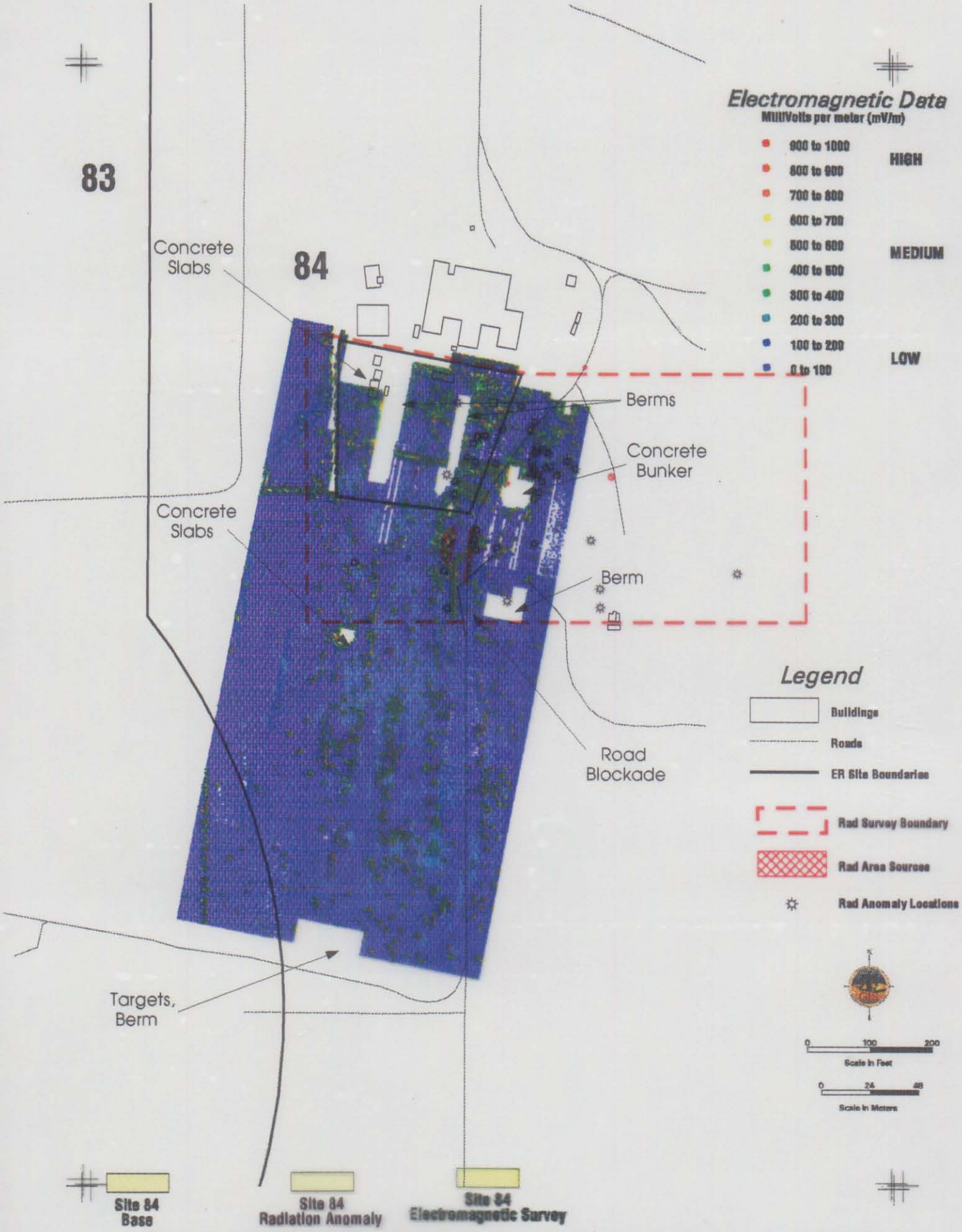

Plate 4. Surface Geophysical and Radiation Surveys at ER Site 84, Technical Area III

October 13, 2003

ADDITIONAL /SUPPORTING DATA

CAN BE VIEWED AT THE
ENVIRONMENTAL, SAFETY, HEALTH
AND SECURITY (ES&H and Security)
RECORD CENTER

FOR ASSISTANCE CALL
844-4688

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